PREFACE.

LIKE the other volumes which make up the present series of technical works, the matter of this volume originally appeared in the pages of the periodical well known as *The Technical Journal and Industrial Self-Instructor*.

For reasons which it is not necessary to detail here, the subject of carpentry was not completed in the journal just named. That deficiency has been now supplied by a special section, which takes up the important subject of timber. This, so far as the somewhat limited space at the disposal of the Editor admitted, has been made very exhaustive; its main features being generally so fully detailed, that the student of the general arts of carpentry and joinery—in both of which timber, generally known and designated by the specific term of wood, the material mainly used—will find nearly every point of importance described.

The arts, which from another point of view may also be described as sciences, of *carpentry* and *joinery* are so cognate to each other, the operations of one being frequently repeated in the other, the scale or size of the special work almost the only point of difference, that it has been decided to combine the two treatises in one volume. This plan possesses so many advantages that it will, no doubt, be appreciated by the

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THE CARPENTER AND HIS TECHNICAL WORK.

Introductory.

THE carpenter claims for his calling, that if not the oldest, it is the most honourable of all. In the guild and other processions of the middle and the succeeding ages, and still in modern imitations of them, of which those got up with admirable *vraisemblance* at the fêtes of some of the leading Continental cities, especially of Belgium, are remarkable examples, the carpenters took the first place, claiming this in virtue of the sacredness given to their trade by the fact that our Saviour himself worked in a humble carpenter's shop in old Judæa.

The necessities of shelter from the inclemency of the weather, or of protection from burning sun or chilly wind and rain, would compel man to put his wits to work, in order to devise the best means of securing it. At first the caves and holes of earth, the shade of overhanging cliff and rock, or of some secluded spot in bosky wood or dense forest, would suffice to meet his wants. But as his numbers increased, and with them a desire, if not for higher personal comfort, at least for greater security against marauding foe or plundering neighbour, special structures would be erected. These, if not possessed of much that would add to the personal comfort of their inhabitants, and far from coming up to even an approach in accommodation and construction to the poorest of our huts now, would at least have the great advantage of sheltering from the roughest of the winds or the heaviest of rains; and the then still greater advantage of strength to resist attack.

Timber the Earliest Material used in Construction.

The very abundance of timber, in those early days when lands were covered to a great extent with forests, would naturally attract attention to it. It was moreover the easiest to be used for constructive purposes, for it was met with in as wide a variety of shapes as in that of dimensions. And there is little doubt that the first habita-

tions of men were composed of branches of trees roughly put together. But it was long before the art of working in timber had so far progressed that large and imposing structures could be erected with it. We can, without a great stretch of imagination, conceive of its gradual progress. At first, tools being of the rudest (possibly sharp-edged flint or shell for cutting, and heavy stones for breaking asunder) the very smallest branches, mere twigs, would be used; the interstices between them, fitted up, as they would be, in roughest fashion to form a shelter, being filled in with the smallest of twigs, or even leaves possibly, plastered over with mud or clay. But with better tools and growing skill the branches of trees would be severed from their parent stems, and these planted as posts at wider intervals, would give points of support, between which smaller branches would be placed, and between these the intertwined twigs and leaves as before. It would be some time before the huge trunks themselves could be made use of. No doubt, long before axes sufficiently sharp and strong to sever them could be available, fire was used to level the lordly trees of the forest to the ground; possibly also for long to separate them into manageable logs or lengths. But when tools capable of dividing, as saws, of cutting or slicing, as axe or adze, came to the aid of man, a new era in the art of working in timber would be opened up to him.

Tools used by the Carpenter.

The tools of the carpenter are but few in number, and to a great extent of extreme simplicity of character, as compared with the tools more or less elaborate in make, but in number considerable, which the requirements of some of the mechanical arts demand. But few as the tools of carpentry are, they have a history which, if only known to us in its full development, would be seen to be full of most suggestive incidents and of practical value withal. But of this we may be sure, that the progress of the art would be dependent on the progress of tool-discovery and tool-making. At first the work of the carpenter would be of the simplest; his tools by which that work was, so to express it, bounded or limited, being themselves of the simplest. The smallest-sized timbers—or rather, as we should say, trees—would be dealt with,—long, indeed, after the rudimentary structures we have already alluded to, which would be more correctly called mere booths, or arbours to use the popular term, were replaced by erections which could be classed under the more imposing name of structures. But these could not be made without tools. Tools, therefore, would be invented; and, as we have said, would naturally at first be of the simplest and lightest character, which could only do the

simplest or the lightest of work. The subject of tools will be treated of under a special head, so we leave it for the present and pass on to

Carpentry as a Constructive Art.

Considered as a purely constructive art, carpentry differs from masonry, the chief work of which consists in providing structures of stone for the shelter and convenience of man as much by the nature of the materials which it employs as by the method of employing them. In stonework the stones are generally placed in horizontal layers the one above the other; their weight if they are cut, and the use of mortar if they are rough, or if there are any imperfections in cutting to be remedied, giving them the necessary stability. Thus are formed compact strong walls, broken only by such openings as are rendered necessary by the nature of the building. In putting up timber-work, on the contrary, a greater or less number of squared and properly cut pieces of wood, which can be inclined in any direction, are put together in such a way that the end of the one rests on some point of the length of the other, lending each other a mutual support. The pieces or members thus form light divisions, which have the advantage not only of great stability, but also that of being rapidly constructed; while the whole structure possesses a lightness which is sometimes necessary, and which stonework does not give. It is thus that the carpenter erects with remarkable rapidity houses and buildings of all kinds; that he divides them into stories in the simplest manner; that he builds bridges of all sizes; that he covers the largest buildings; and that his results, often preferable to those obtained from another kind of construction, are generally less expensive.

Some Technical Definitions connected with the Art of Carpentry.

In practical phrase we say that the pieces of timber forming any structure in carpentry are "joined" together, and the different methods of "joining" are in technical phrase called "joints." When two pieces are placed simply in contact with each other, we use the term—used also by the mason in similar circumstances of his materials—"bedded," or say that they "butt," meaning by those terms that the pieces of timber merely rest or press one upon another. When the pieces are connected by means of projecting parts and hollows and grooves the terms above named are employed, signifying that they are joined by what are called "joints." When a number of pieces are so connected firmly together, forming an arrangement designed to serve a special purpose, as a floor, a partition, or a roof, they form what is called in general terms an "assemblage," or more popularly a "framing" or "framework"; this having its special desig-

nation according to the purpose which it is designed in construction to serve. And this framing, framework, or assemblage, is arranged or designed in accordance with the principles of the science which dictate what the methods are of securing stability in the structure as a whole. Those principles come under the general title of the "principles of framing."

Proposed Method of Treating the General Subject—The Practice of Joining Timbers together, or Joints—The Theory and Principles of Framing.

We thus see that there are two departments of the art of carpentry, each of which, while it has its leading principle or principles, has also details more or less numerous. There are two methods by which the pupil can study the art as a whole, first engaging himself with the principles of framing, or what may be called the theory, and by some has been called the architecture of framework; secondly, taking up the consideration of the practical methods by which the timbers, their position and arrangement, have been determined by the design, and this based upon the theory of framing, and in practice worked out with the various joints deemed best fitted to secure the soundest mode of construction and the permanent stability of the whole. We have taken into consideration the general circumstances in which the majority of technical students are placed, and also those of many of our readers who are not directly engaged in industrial work, but still greatly interested with many of its details; and we believe that we shall best meet the wishes of the majority of those two classes of readers by taking up first the purely manipulative or handicraft part of the work of the carpenter—that is, the "joints" he uses in forming framework or framing—thereafter explaining the principles upon which that framing is designed.

The knowledge of the "joints" is very important, inasmuch as when we erect timber-work we should not put up a single piece, however useful it may otherwise be, without seeing beforehand how it will join with the others, and how we shall be able to work it out or practically execute it and put it in its place. Unless we do so, the projected framework would be impracticable. An assemblage of timber or framework, however complicated in appearance and however numerous are the pieces of which it is constituted, is, so far as the department of "joints" is concerned, always reducible to two pieces. After being joined the two pieces are then to be considered as one; and if a third piece be added to this, it does not constitute a joint of three pieces, as the pupil might at first suppose, but is obviously a new joint, and of which the feature is as said above—that is, of two pieces. The first piece, composed say of A and B,

makes the one piece which we call C; the third piece, denominated D, makes up the assemblage; but so far as the "joint" is concerned of D, there are, strictly speaking, only two pieces, C and D. All joints, therefore, require, and only are concerned with, two pieces. It is the combination of pieces which form an assemblage or "framing," although parts of this may be made up of two pieces "joined," or of single pieces of timber only. The reader will perceive, therefore, that the practical work of carpentry—that is, the handicraft skill of the carpenter—consists, first, in joining pieces considered as simple members, and second, in arranging those different members so as to form a framing or framework; this form being dependent upon the character of the office it has to fulfil, or the purpose for which it is designed. And, as we have already said, in designing this framework or assemblage of single pieces or members, an acquaintance with certain physical facts is desiderated, and a knowledge of certain mathematical principles and geometrical constructions is further necessitated to make these facts available. This part of the subject may be called theoretical carpentry, and its features will be explained in due course in this series of papers, which concerns itself with carpentry as a whole. It might perhaps have been a more logical method to have considered the subject of theoretical carpentry in the first place, thereafter taking up the consideration of the methods by which the requirements of theory are met by the details of practice. But on due consideration we have deemed it most likely to help the pupil, whom we suppose to be for the present ignorant or nearly so of the subject, to arrive at a rapid knowledge of its practical details and principles or theory, if we take the details first. In illustrating and explaining these, much will be given by us, and we hope much will be acquired by the pupil, which will bear upon the theory and make its various points to be more easily understood by him. Having by this method of dealing with the whole subject a knowledge of what may be called the handicraft part of the work, he will be able to give, as it were, a concrete form to much of the abstract reasoning involved in the explanation of the theoretical principles upon which framing or framework is based. The first department, therefore, to which we direct the attention of the pupil is that of

Joints and Various Points connected with them, treated of in a number of Consecutive Paragraphs: General Character of Joints.

When two pieces of timber are to be joined, the relation they have to bear to one another determines the characteristic feature of what is technically called the "joint." First, the pieces may be at right

angles to each other, in which case the joint is called a square joint; or the pieces may be so placed in relation to one another that the one is placed at an angle to the other, when the joint is said to be oblique, or is sometimes designated as a mitre joint—although this last-named joint is one of a special character, more closely relating to the work of the joiner than that of the carpenter; some of the work of the joiner overlapping, so to say, that of the carpenter, and *vice versâ*. The exact character of the term mitre joint will, therefore, be explained and illustrated fully in the volume in this series entitled "The Joiner"; for, strictly speaking, a mitre joint is one in which the angle is invariable, and is used to join pieces which come under the first category named above—that is, of pieces at right angles to each

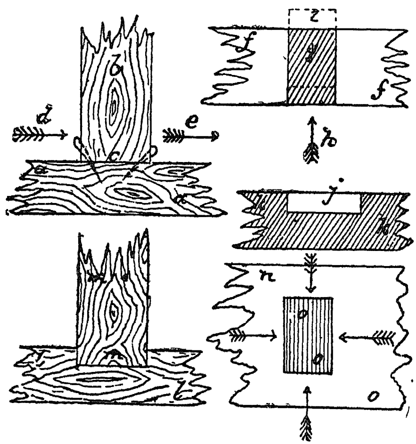

Fig. 1.

other. In addition to the joints for pieces or members at right angles and those oblique, there is a third class in which a piece, constituting a single timber, is made up of two stouter pieces, the conjunction being formed by a particular class of joints. We have thus three classes of joints to consider; and of these we take up the first, which concerns itself with two pieces, one at right angles to the other. But before proceeding to take up the systematic description of the classes of "joints" and the numerous varieties under each class, we shall give, as introductory to the general subject, illustrations of what may be called representative or typical forms of joints under the classes we have named, together with sundry considerations

connected with the general subject, and some remarks as to the way in which the joints were introduced, or, as we might put it, invented or discovered.

Representative or Typical Forms of Joints.

Fig. 1 represents the two simplest forms of the square joint

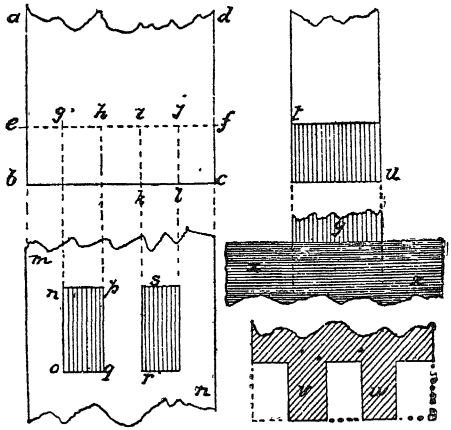

Fig. 2.

named in last paragraph, in which the piece *a*, or member, is at right angles to the other, *b*. This will be described in detail when

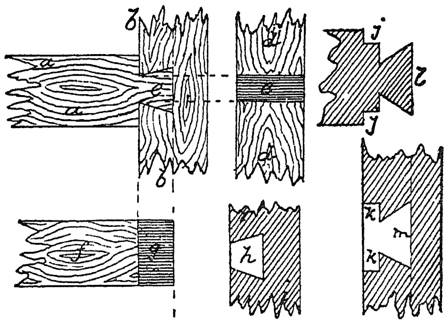

Fig. 3.

we come to the systematic consideration of all the classes of joints with their varieties. A much higher variety of joint of this class is

illustrated in fig. 2, which represents the double variety of the most important of all joints of the class, known as the mortise and tenon joint, of which more hereafter. In fig. 3 we give another variety of "square joint," in which one piece, as *a a*, is horizontal and jointed to the other piece, *b b*, which is vertical, at a given point of its length or height. This illustrates the form of mortise and tenon joint known as the dovetail mortise and tenon. In fig. 1, Plate I., the

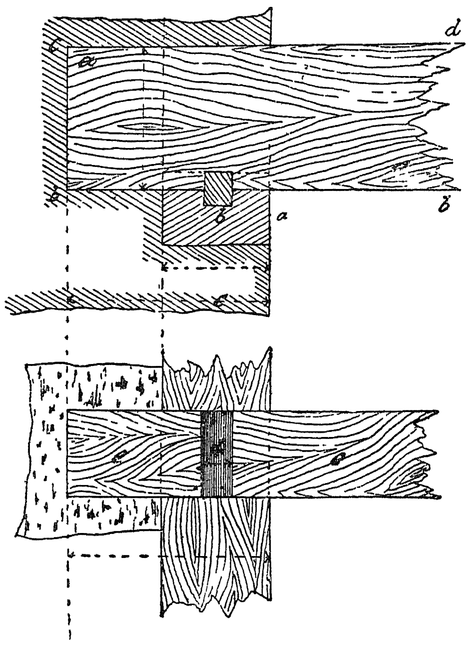

Fig 4.

reader will find another illustration of this class of joint, in which the king-post *a* is joined at right angles to the tie-beam *b*. More forms of joints of this variety will hereafter be illustrated. In those three varieties of the first class of joints, or "square" joints, figs. 1, 2 and 3, and fig. 12, Plate I., one of the pieces is horizontal, the other vertical; but in fig. 4, while the two pieces are still at right angles to each other, the piece called the "wall plate," as *b*, runs at

right angles to the line of "tie-beam," *a a*. Fig. 5 is another example of this variety of joint, in which the piece or "flooring joist," *c c*,

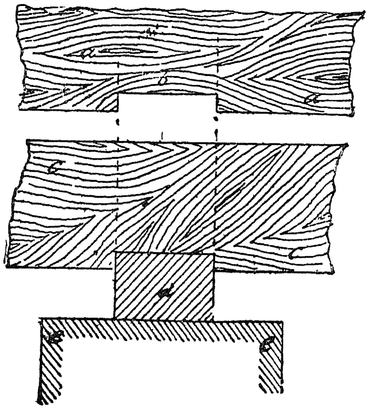

Fig. 5.

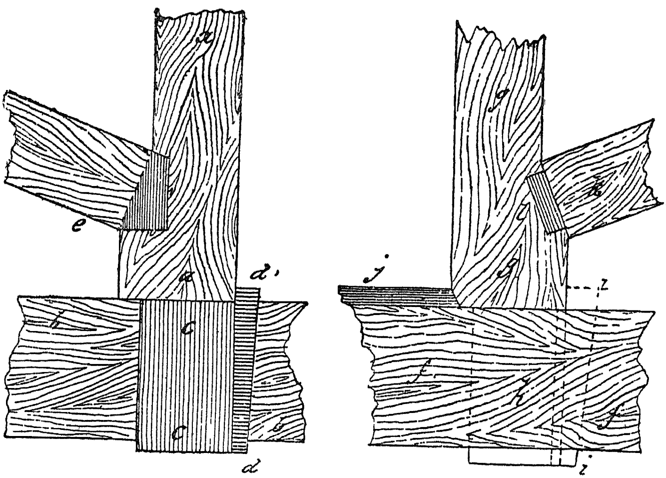

Fig. 6.

crosses the "sleeper" plate *a* at right angles, but both are horizontal. Of the second class of joints, or "oblique joints," we give an example

in fig. 6, in which the piece or "strut" or "brace" *e* or *k* is oblique to the vertical piece or "queen-post" *a a* or *gg*. In fig. 12, Plate I., another illustration of an oblique joint is given, in which the piece or "strut" *e* is joined obliquely or at an angle to the piece or "king-post" *a a*. Other forms of oblique joints are shown in figs. 8 and 11 in Plate I. In fig. 7 we give another example of an oblique joint, in which the "strut" or "brace" of which the foot joint is at *a* is

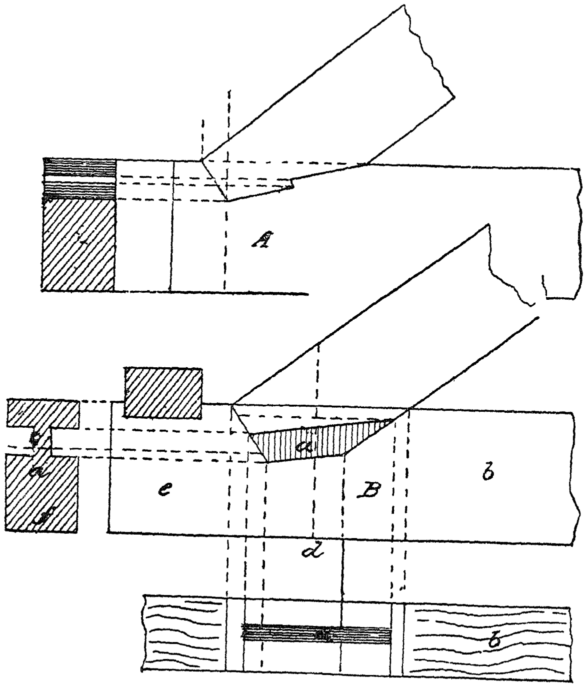

Fig 7.

oblique to the "tie-beam" B. This will be described in a future paragraph. In the examples in figs. 8, 11, and 12, Plate I., the oblique piece and the vertical piece both lie in the same plane—that is, their faces are parallel and run in vertical lines. In fig. 8 we illustrate a form of "oblique" joint in which both pieces lie in a horizontal plane. In the upper diagram the oblique member or

piece *c* terminates at the outer edge of the piece *d d*. In the lower diagram the oblique piece *i i* crosses the other piece *k k*, so as to extend on both sides of it. In Plate I., in fig. 6, an example is

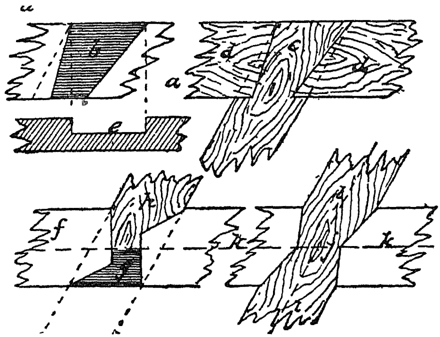

Fig. 8.

given of an oblique joint in which one piece, the "collar beam," as *a a*, crosses horizontally the oblique piece, namely the "rafter" *b b*. We now give illustrations (figs. 9, 10, 11) typical or representative

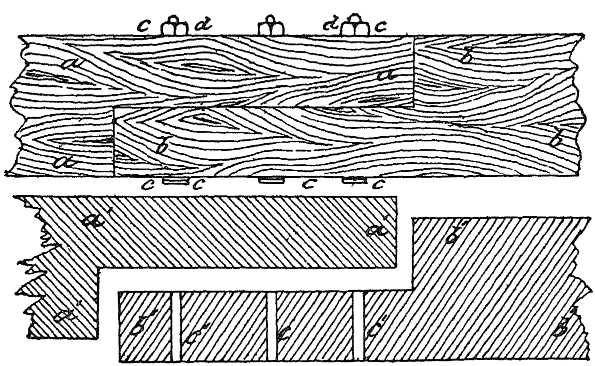

Fig. 9.

of the third class of joints, in which a long piece—considered as one member—is made out of two shorter pieces. This method of joining is known generally as "scarfing." The simplest form of this

class of joint is that known as the "half lap," illustrated in fig. 9. Fig. 10 is a true scarf joint, and fig. 11 another example. All the

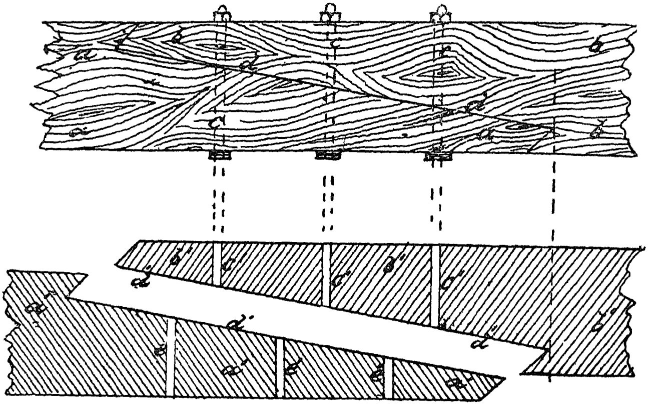

Fig. 10.

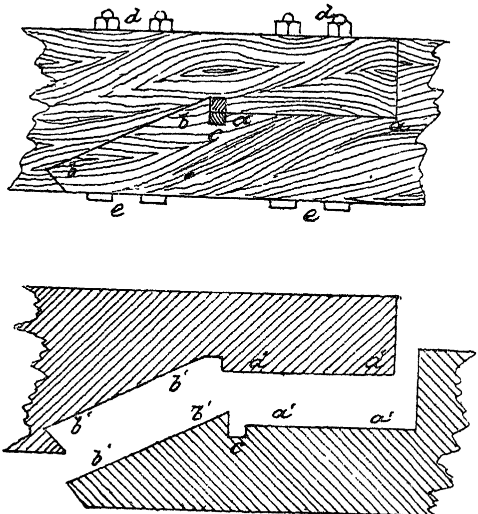

Fig 11.

practical points connected with these joints and with other varieties, of which these are the typical examples, will be fully described in

their appropriate paragraphs in succeeding chapters. Meanwhile we proceed to offer some remarks on

The Origin of Joints in the Work of the Carpenter—Practical Points connected with the Subject

Although some of the points connected with the origin of joints are more or less conjectural, still there is good ground for believing that the early work which led to the discovery of the joint as a feature of carpentry followed very closely the lines we shall presently indicate. But apart from other and obvious considerations connected with the subject, the youthful reader will possibly be led by what is given to see the practical advantages which will accrue to him in his after life from thinking out or over the various departments of his work. One of the shrewdest and most practical of our technical authorities has remarked that the great task before our industrial workers, and those who are being educated and trained to add to the ranks of these, is to learn to think, or in other words, to acquire the habit of thought. That this once established, there will be no doubt of future and further progress, as aids and helps of every kind, either in the form of technical classes or technical books, are at hand to lead the technical workers to exercise their thoughts in practically useful directions. And that there is a vast deal of truth in this dictum of our eminent authority, no one who knows what practical work is and what workmen are, can have any doubt. Everything, therefore, which tends to cultivate this habit of thinking possesses a positively practical technical value. We proceed, therefore, to the subject of the present paragraph—believing that our remarks will not only be practically interesting to the tyro, the beginner in the study of the art of carpentry, but we have some reason to hope that they will be of some suggestive worth to those who, while they are well acquainted with both its theory and practice, have not as yet attempted to trace to its origin the method by which both were arrived at, and by which the early labours of the carpenter were raised from the position of mere matter of handicraft skill and dexterity to the dignity of a science.

In proceeding to trace the progress of the art of carpentry, so far as it bears upon the general subject of "jointing," in some of its more special aspects, we have to notice, as already stated in an early paragraph on the tools of the carpenter, that in the erection of timber structures, those being for a long time confined wholly to domestic purposes, light timbers for obvious reasons would be used in the first instance. And this if for no other reason than that they could be more easily worked to the desired lengths and shapes

by the simple tools then used, to say nothing of the greater ease with which they would be handled and placed in position. But in some instances longer and stronger pieces would be required for some special purpose than could be conveniently obtained or ready to hand. This would naturally lead to the consideration of methods by which the desired piece of a certain length could be obtained by the junction, in some form or another, of two or more of the smaller pieces at disposal; and thus the system of "joints" would be begun to be established Joints at first would be of the simplest character, what one might call the rudimentary forms being only used. Thus we can conceive that amongst the first joints (so to call this simple arrangement) required would be a method of joining two short pieces together in order to make one single long piece. The easiest way to do this would be as roughly represented in fig. 12, in which the end of one piece, as *a a*, would be passed over the

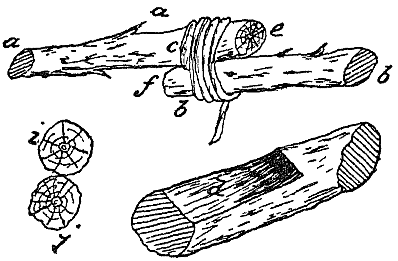

Fig 12

end of the other, as *b b*, the two being tied together by means of some simple ligature, as *c*; very frequently, as may still be seen in some semi-civilized parts of the world, some vegetable fibre or willow withes being used for this purpose. But this joint would depend for its strength wholly upon the strength of the bond or tie at *c*, and on the way in which this was tightly drawn and tightly secured. And at the best it would be a weak joint, the parts being easily moved from side to side, as the touching surfaces of the two parts bearing upon one another would be of the smallest—namely, points or parts of a circle, as at *i* and *j*. To make them lie more "sweetly" together, to use a term frequently employed in mechanical construction, a broader surface would be requisite, so that there would be but little rolling or rocking motion one upon another: and it would take no great exercise of mechanical ingenuity to discover that flattening the ends of each, as at *d*, would be found effectual in this way. The two flattened surfaces would be placed together, and to

prevent the tie from slipping off, a notch or two, in which part of it would lie, might follow.

But this system of tying or binding two pieces of short timber together to form a single and longer piece would, even if the two were so securely bound together as to form a strong joint, be the clumsiest possible arrangement. The sense of the fitness of things comes into play much more early in man's civilization than some are disposed to admit; and this would show how awkward were the breaks in this form of joint, as at *e f* in fig. 12, even where the piece was to be used alone. Where timber lengths so joined were to be placed in juxtaposition, or resting upon one another, the awkwardness of the joint would be still more noticeable. We have shown how this joint, awkward as at the best it is, would be greatly improved by giving flat bearing surfaces, as at *d* in fig. 12, to the two parts placed in contact.

The Half-Lap Joint.

Now, we can easily conceive one of the early carpenters or builders in wood, engaged in preparing the end of a piece of timber to be joined to another in this way, being led to try the effect of cutting the end surface away till a considerable depth in each piece was obtained. In placing them together he would find as a consequence that the projections, as at the points *e* and *f* in fig. 12, would be lessened or lowered just in proportion as the cut at *d* was made the deeper. A little thinking out of this consequence would lead him to conclude that a point of depth would be reached some time, in continuing to deepen the cut, as at *d*, which when reached and the two pieces put together, the upper part of the piece *a a* would "range with," so to express it, or be in a line with, the upper face or line of the piece *b b*, or, to use the technical term, "be flush." The same would hold true of the under sides. The position of the two pieces would be as shown at *a b* in fig. 13, the joint between them assuming the form as at *c*. The end of one of the separate pieces would be as at *d c*; and the depth of the part *c f*, or *d g*, would be found to be exactly equal to half the depth, or the two together to the whole depth or diameter of the tree or branch, as at *h*.

Here we have a true "joint"; and following upon that shown in fig. 12, which was in all probability the outcome of the first necessity—namely, to lengthen out short timbers—we may safely conjecture that it was the first true joint used. It is still used, and largely, in carpentry, and in joinery often, and is known as the "half-lap joint," as at *c* in fig. 13, the simple lap (over), or full "lap," being that in fig. 12 at *e f*; at fig. 9, in last section (page 11), we have

given a drawing of a half-lap joint in section, and in figs 10 and 11 later and more advanced forms of what are called "scarf" joints, which grow out of it.

Continuation of the above Subject, with Practical Examples.

In fig. 3 (page 7), we illustrated, as one of the typical joints, a square joint—a method of joining a horizontal piece of timber to a vertical one. This forms one of our most elaborate joints, but we can easily conceive how it was preceded by other forms of a much simpler character, of which probably its first form was discovered in connection with a part of construction which in its direction would be as elementary as that of tying or binding two pieces together, as in fig 12, at *a a*, *b b*. This would be the connecting with a horizontal piece two vertical posts or timbers stuck or forced into the ground to form, say, the side of an enclosing space, as a hut. At first, the enclosing wall, so to term it, of a

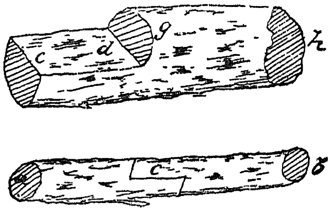

Fig. 13.

hut or hovel would be formed by a series of branches, nearly of equal size, placed close to each other both for strength and for shelter from wind and rain. In process of time it would be seen that the purposes of shelter would be obtained as readily, where shelter was more essential than mere strength, and without the use of so many thick or strong branches, by having the stronger ones placed at intervals in the ground, as at *a a*, *b b*, fig. 14. The tendency of the posts to separate from or to fall towards each other, if left unsupported—a tendency the stronger the higher the posts, so to call them, or the thinner they were—would be counteracted by introducing a third piece of timber—technically now called a "member." This would naturally be placed horizontally, as at *c c*, and at first would be secured to the posts at the two points in the simplest way—by tying them together with some vegetable fibre or the branch, as of that of a willow, as in fig. 12, at *c*. A number of these horizontal pieces placed at intervals in the highest of the posts, as at *d e f*, would

obviously give facilities as holding-places for interlacing the smaller branches, as *g g*, running vertically. Those with their interstices filled up with leaves, or, better still, moss, which would be found to be valuable for many purposes, would form a screen or wall, so to call it, which, for preventing access to wind or rain, would form no contemptible enclosing surface.

But this arrangement, while it would be proved to give strength with fewer strong vertical timbers or posts, would be seen to be an ugly or awkward joint, possessing all the defects of that at *e f* in fig. 12. The desire for even surfaces—that is, the absence of all

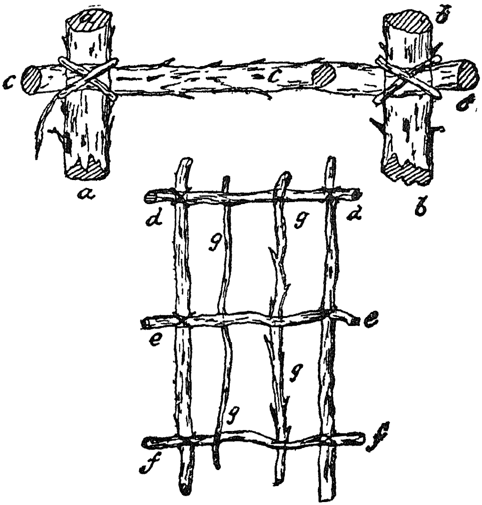

Fig. 14.

projecting parts—would soon be created, and some method of obtaining this in the present instance would follow. Possibly the first attempt to have the horizontal piece at its ends either within the line of the vertical pieces in *a a*, *b b*, fig. 14, or in line with them, and what is technically now called "flush," would be a simple system of "notching." Thus, as at *a*, in fig. 15, the end of the horizontal piece being shaped as at *b*, to go into the notch. In time this notch would be enlarged and made rectangular, to give better bearing surfaces, as at *c*, the end of the horizontal piece *d* being formed to fit as tightly into it as possible. But while this forming of joints would keep the vertical posts, as *a a*, *b b*, in fig. 14, from approaching each

other or bending inwards, it would not prevent them from leaving each other or bending outwards. And if they did so sufficiently far, the ends of the horizontal piece, as *b*, fig. 15, would drop out of the notches, as at *a*, and the connection would cease. The joint at *c* would be better, as it would give the opportunity of joining the end *d* of the horizontal piece tightly into the cut or slot or groove *c*.

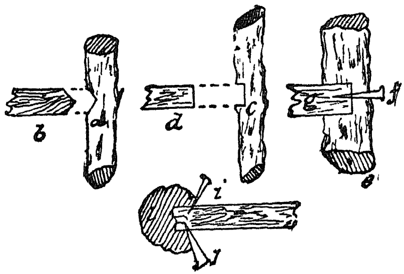

Fig 15.

Trenails, Keys, and Wedges, as used in Carpentry Joints

Simple a contrivance as a "nail" seems to us, it is in reality a great invention, and it would be some time before it was added to the thousand-and-one contrivances which the ingenuity of man has discovered and applied to aid him in his daily work and meet his daily wants. There is little doubt, we think, but that the wooden spike long preceded the iron nail, just as we know the era of timber construction came before that of stone, and gave birth to some of its contrivances and special features. And we can easily conceive of the idea of the spike or wooden nail having originated in some such simple way as passing through a heap or mass of material, such as leaves or brushwood, which it was desirable to keep in one position while lying on the ground, a long and slight and sufficiently strong stick. This passing through the mass and entering the ground or soil would obviously secure the mass, binding it more or less firmly to the soil. Or the idea of the spike may have originated in the desire to bind or keep together the mass of branches, twigs and leaves, etc., which formed the walls or enclosing surfaces of the early huts or hovels of our ancestors. By passing sticks through the thickness of these containing walls at intervals, it would be found that the inner surfaces and outer would be bound together more or less compactly. And it would almost immediately follow upon this, or a similar use of small or short pieces of timber, that they

could be more readily and certainly used if one end was pointed or reduced in thickness. Once the idea of *penetration* took possession of the mind of the constructor, many useful applications of its principle would follow, and his earliest work in connection with his tilling of the ground to receive his tiny crops—the first of necessity of all the arts—would give him this idea of penetration. The wooden spike or "trenail," as in modern technical language it is called (which obviously was once written "treenail," as it is literally a nail made out of a tree), would soon form a very common feature in timber work of all kinds. We have said that the joint, as at *c d* in fig. 15, would depend for its continuance in force upon the tightness with which the end *d* of the horizontal piece was jammed up into the cut or groove *c*. But as timber shrinks and swells—contracts and expands, to use the technical terms—according to the dampness or dryness of the atmosphere; in dry weather the joint thus secured by jamming up would loosen, and the connection between the pieces would cease or be weakened. But the spike or trenail would obviously come in here to serve a useful purpose. It might be used in the way as shown at vertical section of a post *e e*, fig. 15, the spike being driven in from the back, as at *f*, penetrating the end of the horizontal piece *g*. Or it might be driven in from the sides, as at *i*, in sectional plan of the post, at *l*; or two pins or trenails might be used, as at *i* and *j*, one driven from each side. The wooden "key," as it is technically termed, is another contrivance for keeping two pieces "jointed" well secured together, and frequently used to prevent the one piece slipping or being moved away from the surface of the other piece. Its use in this last way is illustrated in fig. 4 (*ante*, p. 8), given in the paragraph entitled "Representative or Typical Forms of Joints," where its position in each section, as at *b*, is shown. The "key" is in this and in similar work a small block generally square in section, and of length equal to the "scat" or groove into which it is passed; the length of the form *b* in fig. 4 (*ante*) being equal to that of groove *d* in lower diagram. Grooves or scats are cut in the lower edge of the upper piece *a a*, and in the face of the lower piece as at *d*, and the "key," as *b*, being forced into the groove *d*, the upper piece, as *a a*, is placed in position when the key *b* enters or is forced into the groove on its lower edge. A wedge is another form of key, and is so called from its tapering form. One form and mode of using it is shown in fig. 6 (*ante*) at *d d* and *i i*. Many examples of the use of trenails, keys and wedges will be found in succeeding chapters, and also of "iron screw bolts" and iron "straps," which are much used in modern work to secure timbers together.

Interpenetration a Distinguishing Characteristic of Joints in Carpentry.

Allusion has been made in the preceding paragraph to the principle of penetration as one of great importance in the art of carpentry. The pupil will perceive, as he proceeds to consider the matter to be given hereafter in this series of papers, how this principle, either in its partial or full development, is concerned in nearly all the operations of carpentry. It is the vital principle on which all joints or junctions of timber where one piece is connected with or supported by another piece chiefly depend. Some of the developments of this important principle constitute a series of problems the most interesting, as some of them are the most intricate, of what may be called the "geometry of carpentry." (See the volume in this series entitled "The Building and Machine Draughtsman.") The first, as it is the most simple of the practical methods of carrying out this

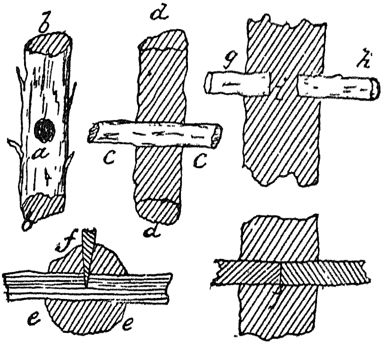

Fig. 16

principle of penetration, would in all likelihood be the forming a hole or aperture, as *a*, in fig. 16, passing through from side to side, in one piece of timber, say a vertical post, as *b b*. The horizontal piece to be supported, as *c c*, may be passed through, as in section of post *d d*, and it may be secured from slipping by the spike *f*, called popularly a "pin," or in technical phrase a "trenail," or a "key" might be used, passing through the post *e e*, and penetrating the horizontal piece as shown. In place of using one long horizontal piece, resting it in the aperture in the post, in or about the middle of its length, two short pieces will give the same result, one being passed—"entered" is the technical phrase or term—from one side, as at *g*; the other from the opposite side of the hole, as at *h*. They might stop short of meeting in the interior of the aperture,

leaving a space, as at *i*, between them; or they might have been brought in contact with each other, as at *j*. When so placed in contact with each other the one piece is said, in technical terms, to "butt" against the other, and the ends of each piece constitute what is called the "butting face" or surface.

We have in preceding paragraphs given illustrations and descriptions of what we have designated as "representative forms" of joints, and of the probable way in which joints originated, or were invented. Before proceeding to take up the systematic consideration and illustration of the different classes under which the representative forms named are ranged, we deem it best to introduce here, as connected closely with what is to be given under this section of our work, some remarks, and to give a few diagrams illustrative of "framing" or "framework," and of some points connected with its original introduction. And as preliminary to these, we preface them by some remarks on

The Methods of Dealing with Timber, Trees, or Parts of Trees, in the Early Constructions of the Carpenter.

Timber would for long be used in the "round" (see volume in this series entitled "The Timber Dealer"), to employ a modern technical phrase still used to denote this the oldest employed of forms of the material. It would take some time before tools were so perfected that the round timber could be formed into timber with squared sides or with flat surfaces. The tool for doing this would, in all probability, be the axe; this followed by the adze, which is simply the axe with its edge so turned in relation to the handle that it can be used for slicing off plates, so to call them, from the surfaces of timber in a way much more conveniently applied and more rapid in its work than the axe. The chisel would soon be invented, and its use for smaller work would soon be appreciated. The saw would early and for long be the great tool of the carpenter; for with it he could do almost every kind of work required, even for the more complicated and complete structures which would follow on the simple booths or huts of branches, twigs, and leaves.

As construction improved, the value of flat surfaces would be seen, if in nothing else than in the closer joint which could be secured than by the use of round timbers, which could only touch at one point in the circumference, leaving rounded or hollow surfaces on each side. This we roughly illustrate in fig. 17, in which *a a* shows the good joint formed by two flat-surfaced pieces of timber lying together. It is a narrow point only at which the two round branches *c*, *d*, can touch, leaving the hollow spaces *e*, *e*, on each side. The

inequality of the joint is, however, still more clearly shown in looking at the sides or along the length of the branches, as at *f f* and *g g*. Branches are often very crooked, and it would not be an easy matter to find two branches so well matched that the hollow in the under side of a branch, as at *h*, could be filled exactly up with the rising or swelling part of another, as at *i*. Much more frequently would

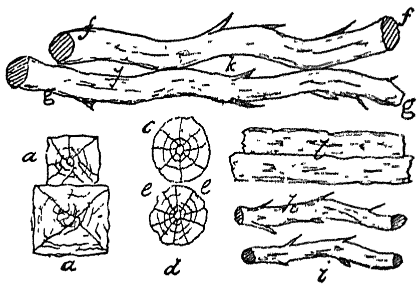

Fig. 17.

the case be as at *f f* and *g g*, where hollow places—which would form holes—would be formed, as at *j*, *k*. The infinitely better joint obtained by using two flat edged pieces straight in the direction of their length is illustrated at *l*.

The splitting of round timber, or of a branch, as *a* in fig. 2 (*ante*), in two—in which operations the value of the " wedge," as at *b*, driven

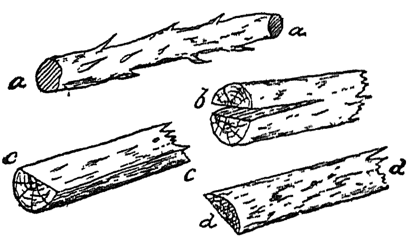

Fig. 18.

by the "mallet" or hammer, would be early ascertained—in the direction of its length, would obviously give two flat surfaces, one to each half, as at *c c* and *d d*, fig. 18. By using the axe, the adze, or the chisel, the rounded side of the half-branch, as at *a* in fig. 3 (*ante*), would be made flat also, and the first "plank," as at *b*, would thus be formed. Its breadth would be determined by the diameter

of the branch out of which it was cut; its thickness by the extent to which the rounded side would be flattened down. The plank so formed would naturally have its upper surface of different breadth from the under, giving as a consequence sloping edges, as at *c c*, *d*, or *e*, fig. 19; to make the "board" or 'plank" a perfect rectangle in section, as at *f*, so that its edges would be square to the surfaces or sides, the sloping part, as at *g e*, would be cut off, so as to leave the edge vertical, as at *h*.

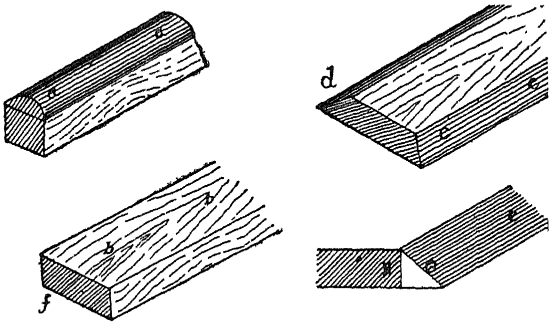

Fig. 19.

The Cutting up of Trees, or Parts of Trees, into Timber for the Early Work of the Carpenter.

The uses to which flat-surfaced boards or planks could be put would rapidly multiply as construction and the consequent desire for comfort demanded by many consumers progressed. And when saws could be made large enough and strong enough, they would be soon and extensively employed in cutting up or dividing in the direction of their length round timbers of such diameter as would give more than the two planks or boards which the method illustrated in fig. 18 would yield. This process is roughly illustrated in fig. 20, in which *a b* is supposed to represent the end in section of a tree or a large branch of it. By sawing down on each side of the central point, as at *c c*, *d d*, the plank or board of greatest breadth, as *c c d d*, would be got which the piece of timber would be capable of giving. By again sawing down vertically at various points, each remaining half, as *a* and *b*, so many boards, forming altogether a series of which *e e*, *f f*, is a rough representation, would be obtained; *e e* representing the boards or planks yielded by the part *a*, *f f* those by the part *b*, the central one *g* corresponding to *c c d d*. Being cut out of a circular bole or branch of a tree, the edges would be more or less

rounded, as at *h*, *i* and *j*; these could be made square by cutting off across the dotted lines either by saw, axe, chisel, or adze.

In like manner, when beams capable of either supporting or carrying heavy weights were required—as they would be as the desire to have larger and better structures increased—they could be cut out of boles or trunks of trees or of large branches, somewhat after the

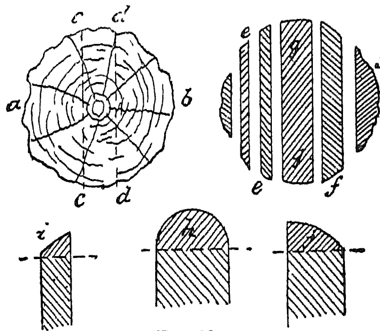

Fig 20.

fashion shown in fig. 21. We have alluded to the value of flat surfaces as being early discovered by the carpenter. These would be specially useful in the case of beams supporting heavy weights, inasmuch as they would enable the beams to be placed in position much more securely than if their surfaces were rounded. In other words, a flat surface would better give what in modern technical

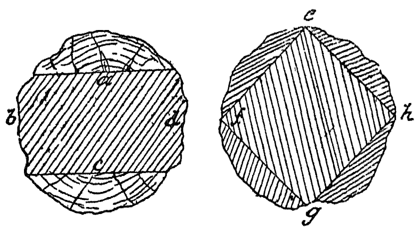

Fig. 21.

phrase is termed a "good bearing surface" than would a round, which would obviously present a rocking or rolling surface when lying on a flat place, technically now called a "bed" or bearing place. The quickest way to get a beam from a tree or branch would be to cut or square off two sides only, as at *a* and *c*, fig. 21, giving two corresponding flat surfaces and two rounded edges as at *b* and *d*.

A square beam would be obtained with four flat sides by cutting or squaring off the four rounded parts as at *e f g h*. The reader will find at an advanced part of the present volume a method of finding the strongest section of a rectangular beam which can be cut out of a round bole or trunk of a tree. Further on, also, he will have various diagrams given him illustrative of the points which regulate the forms of beams calculated to support the greatest weights, and how the pressures exerted upon beams are measured and estimated.

"Framing," or "Framework," an Assemblage of "Pieces" or Parts of Timber in the Construction of the Carpenter.—Some Technical Points connected with the Subject.

So far as we have gone, we have been concerned chiefly with the methods of joining timber together, in using and in cutting it up, and with explaining in conjectural fashion the possible way in which the methods were discovered by the early workers in timber construction. But we have only incidentally touched upon what constitutes true "framing." By this term is meant an arrangement of timbers more or less numerous by which with the least weight or bulk of material the stringent form can be obtained. This arrangement is called an "assemblage," or an "arrangement," or often simply a "framing" or "framework," and may take various forms, of which floors, partitions and roofs are those principally met with, although there are numerous other forms, such as those in scaffolding and framework used in the construction of public works, as harbours and other departments of civil engineering work. Of all of these, illustrations in abundance will be given in the course of these papers. The assemblage of any framing is, as we have said, made up of a number of independent or separate parts joined or connected together; and to these parts the name of "members" or "pieces" is technically given. Those assume different positions, and take different names—such as girders and beams, rafters, purlins, struts or braces, ties, king posts, and the like. Of all these also, and the joints used in connection with them, the pupil will find ample illustration in succeeding sections.

In endeavouring to trace the gradual progress of the art of carpentry in one of its leading departments, the pupil will very much have misconceived our aim if he supposes that we have been giving what may be considered as matter which is merely interesting, or, as some may even consider it, only amusing. It may be this; and we are so far from objecting to any study being so lightened up that we would, on the contrary, advise all young students to use

such "legitimate means" as judicious amusement affords to lighten and instruct them in its necessarily dry details. But if what we have said be amusing to some, it is something, and designed to be something, much more than this. The pupil will have read to little purpose in the direction in which we have designed to lead him if he has not perceived the practical aim of what we have given, or has failed to gather from it much information of a thoroughly useful character. Whether the conjectures we have given in preceding paragraphs, and are about to give in those to follow, be more or less accurate, or altogether fanciful, they actually embody some of the most important principles of the art of carpentry, the fuller exposition of which will be found in succeeding illustrations and descriptions. And if our conjectures as to the details of progress, or what was likely to be in early practice, appear to him to be feeble, or to possess no force at all, we should recommend him to endeavour in somewhat similar manner to our own to conceive for himself such steps as would probably be taken by the first workers in timber. This will possess more than the mere advantage—though that in itself is worth something—of ministering to the intellectual training which the habit of thinking out for himself the different points of the art is calculated to give; it will moreover aid him greatly in his estimation of the principles upon which that art is founded.

We have said that we have not as yet considered closely the subject of "framing," purely so called, and the meaning of which we have but just generally described. In much the same conjectural way we have followed, or attempted to follow, the progress of the art in two of its departments, we shall now attempt to follow it in this the most important of those. And here we shall be, if not disappointed, much mistaken if the pupil does not derive some practically useful information as to the leading principles upon which all framing is constituted.

Gradual Development of the Art of Designing and Constructing Framing or Framework by the Early Carpenters.—Simplest Elements of Farming

The knowledge of those principles would naturally be a matter of slow development; and the first or tentative attempts to erect structures of timber possessing the greatest strength to resist opposing pressures or sustain heavy weights, would gradually lead up to a study of the reason why certain arrangements of pieces of timber gave greater strength to the structure than other arrangements. In this, as in other of the mechanical arts, the practice of certain contrivances would precede the principles, and these would only be deduced from the simple practice when men had further advanced

in intellectual analysis and synthesis, or in what is called scientific reasoning; and still higher developments in practice would lead out from still deeper study into the application of the first or elementary principle which practice would display. This practice would, in one sense, be forced upon the early workers in timber from the mere necessities of their position. They would feel that their growing wants and the claims of a higher civilization demanded, if not more and more elaborate, certainly stronger and still stronger structures. Nor would these wants and claims be altogether of the class which some think alone constitute true civilisation. Man has been defined as a fighting and a quarrelsome animal, sharing in this way with the brutes a capability of inflicting suffering and loss upon his neighbours. And as ill weeds are said to grow apace, we may very reasonably conclude that warfare, in one or other of its many more or less but always too decided forms, afforded a much earlier impulse for the timber worker to give strong structures for defence, or strong appliances for offence, than any necessity arising from the pursuit of greater and more humanising influences. The mechanical arts have, as a rule, showed many of their best and earliest developments in connection with what is called the art of war. Hence trenchant sword-blades were common long before domestic knives or scythes for the grass-mower were met with, and spears received more of the attention of the artificer in metals than did pruning hooks. And as the best materials and the finest workmanship were given by the metal artificer to the implements of warfare, so was it, we may reasonably conclude, with the worker in timber. He would for a long time be much more frequently called upon to design and construct a strong structure for defence in war than he would be asked to rear a strong yet comfortable house for time of peace.

We may reasonably conjecture that the first element of a piece of pure framework was obtained in the way illustrated at *a b c d*, fig. 22. We may suppose the post *a b* to be one fixed by being made to penetrate the soil or ground, that part of the post or stake being pointed, as shown by the dotted lines. It was desired that the post so far firmly fixed by its hold or grip of the soil should be capable of resisting any attempt to make it swerve from one side to the other. We may suppose that whatever pressure was likely to cause this elevation from the vertical would come from the side and be represented by the arrow *e*. A very slight knowledge of the way in which a pressure was put upon a post so placed, and of that in which it would be best resisted or neutralised, would give the suggestion of propping it up—to use the popular phrase—by putting a piece, *c d*, in the position shown in fig. 22, one end pressing against

the post, as at *c*, the other pressing on or penetrating into the soil at *d*. The simplest way of securing and keeping up the connection of the end *c* with the face of the post, *a b*, would be to notch the post, as at *f*, slightly tapering off the end *c* of the prop *c d*, as shown at *g*. This arrangement would dispose of any force in the direction of the arrow *e* "pressing" on one side of the post, or

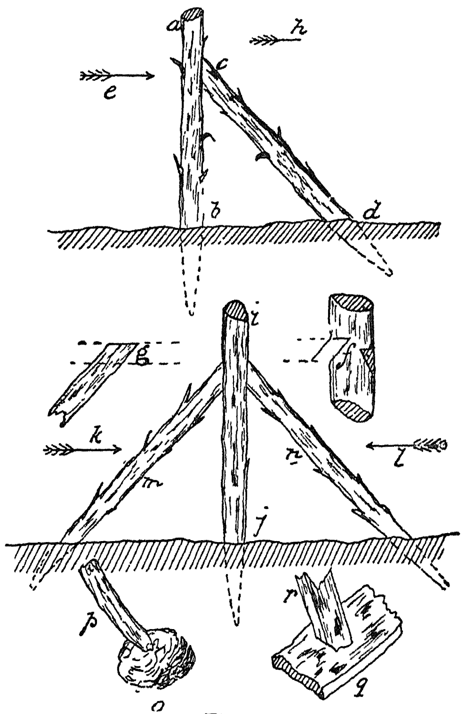

Fig. 22.

"pulling" on it in the direction of the arrow *h* from the opposite side. To oppose a pressure on a post, *i j*, fig. 22, "pushing" in one direction, as shown by the arrow *k*, and another "pulling" or hauling in the opposite direction, as indicated by the arrow *l*, a repetition of the contrivance adopted at *c d* on the opposite side of the post would so far meet the case. It is, of course, obvious that much of the capability to resist any of the pressures here named would

depend upon the strength of the prop *m* or *n*. If weak it would bend, and possibly break. The early workers in timber, however, would be careful to use timber strong enough, and this we know they did from the examples of carpentry which have come down to our time in old buildings. But strength alone would not secure the prop doing its work, or rather performing its office properly. We have alluded in preceding paragraphs to the value of the principle of "penetration," and the importance of "bearing surfaces." But while valuable in one direction, penetration is a source of loss in another. While it is obvious that the end *d* of the prop *c d*, fig. 22, would have a good position or anchorage given to it by being inserted in the soil, it is equally clear that under pressure put upon the prop by any force "pressing" in the direction of the arrow at *e*, or "pulling" in that of the arrow *h*, it would have a tendency to penetrate deeper into the soil. And the further the point *l* sank then, the more the point *c* would yield, and the greater would be the swerving of the post *a b* from the vertical or its strongest position.

Technical or Practical Facts learned from the Foregoing Illustration.

We have alluded to "bearing surfaces,"—and as to their value the early workers would learn somewhat from their experience in carrying out such a contrivance as that illustrated in fig. 22, at *a b c d*. It would show that mere strength would not enable a member, such as a prop, to fulfil the duty expected of it. Neither would the accuracy of its position in relation to its connected members. They would soon find that something more than those two otherwise essentials would be required. They would find this to lie in the having a good point of resistance, and in this they would see also the value of the bearing surfaces we have alluded to. Still following out the conjectural style of inquiry we have hitherto adopted, and which, as we have endeavoured to show, is likely to give the pupil many practical suggestions, we may conceive the following to have been the experience of an early timber worker. In erecting the arrangement or assemblage of timber illustrated in *a b c d*, fig. 22, he found that on first inserting the prop *c d* it appeared to strengthen or support the vertical position of the post *a b*. But as the pressure was brought to bear upon this which we have supposed to be exerted in the direction of the arrow *e*, he found that somehow the post continued to lean towards the arrow *h*, and on examination he would find that this happened precisely as the end *d* of the prop *c d* sank deeper and deeper in the soil under the pressure communicated to its upper end *c*, where it was connected to the prop. The pressure on the post still continuing, he would at one point see that it was

now able to resist it, and that it remained steady with no inclination to move in the direction of arrow *h*. Curiosity rightly directed is a valuable characteristic in man, and is one of those faculties with which he is endowed, which, when it is judiciously exerted, has enabled him in times past and still enables him to push inquiry till valuable discoveries are often made; and always at the least, at all events, to obtain much valuable information. Against a vain and idle curiosity we need give here no word of warning, as we trust it is unnecessary in the case of our readers. This feeling of curiosity we conceive as prompting the early worker in timber, in the circumstances named above, to try to ascertain how it was that the pressure tending to bend or force aside the post *a b*, fig. 22, was at last arrested. To gratify his curiosity, then, we suppose him to have scraped or dug away the soil surrounding the end *d* of the prop, in order to lay its extremity bare. In doing so he found that its extreme end was pressing against a stone, with which it had accidentally come in contact. Correct curiosity leads generally to inquiry, and inquiry to conjecture, and this is put to the test of practice; he therefore put more pressure upon the post, and found that this caused pressure on the stone. Further investigation led him to discover that this pressure caused the stone itself to "give" or "yield," and to sink into the soil more or less easily; and this not in a direct line, but more at one corner than another. This he found arose from its shape; and at last a gleaming of the fact came into his mind—that the larger the surface or the flatter the stone the better is it able to resist the pressure. Further, that the position of the point of the prop *c d* itself in relation to the stone surface on which it presses affects favourably or otherwise the capability of the stone to resist the pressure of the prop.

We concluded the last paragraph by referring to the use of a flat stone as a surface for a piece of timber to bear or press upon, and stated that independently of the value of its extent of surface, the relation which that bore to the position of the bearing point of the timber prop was an important element in the arrangement. For if the prop was pressing on one corner of the stone, this capability was lessened, and the nearer the end of the prop approached the centre of the stone, the better able, so to say, the stone became to resist the pressure of the prop.

In the form which we suppose to have been his first attempt to use—namely, an arrangement like the one in fig. 22 (p. 149), at *a b c d*—we are considering that the end *d* of the prop *c d* rested or pressed against a very hard and stony soil, difficult to penetrate; its capability to resist penetration of the prop being greater than the

pressure put upon it tending to force it or make it penetrate the soil. Putting the two experiences together, the early carpenter would see that if he wished the prop to perform its office he would require to give it a resisting surface to press against, and that, the softer the soil, the broader that surface must be, to enable it to resist the pressure put upon it—the mere extent of surface aiding its finding the most solid "bed."

The early worker would thus receive two lessons of importance in the art of constructing timber-work: one would bear on the truth that by increasing the surface of any resisting piece or point, pressure would be distributed over a larger area, so that a material which would not bear a certain weight without giving way if that weight was applied over a very small surface, would be found to bear even a much greater weight if the pressure which that weight exerted was spread over, so to put it, a larger area. The second lesson he would learn would be that much of the value of a good bearing surface depended upon the way in which the pressing piece, as the prop *c d*, was connected at its foot *d* with the resisting member, which we have supposed to be a stone; and that it would require to be so made that it would not readily slip away from this. He would soon see that in cases of soft soil a flat piece of timber with large bearing surface would be as valuable as a resisting point as a stone would be; and that the timber would give readier facilities for forming the "joint," so to call it, at the part where the "foot" of the prop *c d* was connected with the bearing surface. Another lesson learned would show how pressure put on at one point in the assemblage or framing of timber was communicated or led to another member, and how this would, in some way or another, regulate the relation which the members bore to one another. A fourth lesson, and of the four the most valuable, if this could be said where all were valuable, would be the use of timber when under certain circumstances placed on the "slant" or "oblique." The value of this principle of "diagonal" or angular position would soon be perceived practically in relation to vertically and horizontally placed timber, in which position only the earliest timber workers used their material.

Further Developments in the Art of Designing and Constructing Framework in Timber.—The "Truss" the Essential Element in all Sound Framing.

We do not say that the early worker in timber would be aware of the fact that he had thus learned important lessons in his art. Quite possible is it that he might simply accept, as a matter of course, the facts he could not help seeing, so to say, and would, without further thought about them, and made thus aware of the

value of the practice, continue to adopt it in his future work. He or some after-worker, possessed of a thoughtful mind, might really appreciate the lessons learned, and in thinking them out might deduce a theory of his own, expressing the reason why or the cause of the practical result of the arrangements adopted. Practice, we may rest assured, would long precede theory, and nearly all steps in advance Thus, although the arrangement or assemblage of timber in fig 22 (p. 149), at *i j m n*, would be found by the early worker to be, as in reality it is, the strongest possible combination within the reach of man; it by no means follows that he who first hit upon its conception—or rather we should say discovered its utility—could or would be able to give a reason why it was so valuable. We have endeavoured to show, indeed, that the arrangement might be accidentally discovered or be led up to by a series of natural steps, which we might say, with some truth, the early worker could not, as it were, avoid making, this being done, as it were, intuitively.

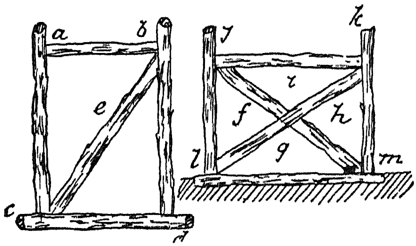

Fig. 23.

The arrangement or assemblage at *i j m n*, fig. 22, is in point of fact what in the art of carpentry is called a "truss," and in it, even in this the rudest or most elementary stage, all the elements of a well-designed modern roof (truss) are illustrated. The great principle which the "truss" exemplifies is the designing of arrangements of timber composed of horizontal and vertical timber only, and which, therefore, are rectangles, either square or such as *a b c d*, in fig. 23, so that the arrangement of the pieces or members give triangles, by the simple addition of an inclined piece or "diagonal" member, as *e*. This forms two triangles, as *a c e b*, *d c e b*; or four, as the triangles *f*, *i*, *g*, and *h*, by the addition of two diagonals, *f* and *h*, between the two vertical posts, *j l*, *k m*, and the two horizontals *j k*, *l m*. But although assemblages or arrangements of timber in which diagonals were introduced, cutting up, so to say, the old or original rectangular forms into triangles,—thus giving the strongest of all forms,—would be long followed, it is by no means to be concluded

that the "reason why" this triangular arrangement was so strong would be understood. We conceive it to be a very probable thing that it was only at an advanced stage of educational civilisation, so to term it, that some thinkers, taking the forms of timber arrangement which practical workers had long adopted, deduced the theory of the truss. And we may rest pretty well assured that it was only by a series of tentative trials or of lucky hits that the full value in practice of the principles we have endeavoured to explain became known to timber workers.

Further Illustrations of the Principle of Diagonal Adjustment of Members or Pieces of a Timber Framing.—Strutting or Bracing of Timbers.—The King-Post Truss.

We have thus illustrated one or two of the earliest applications

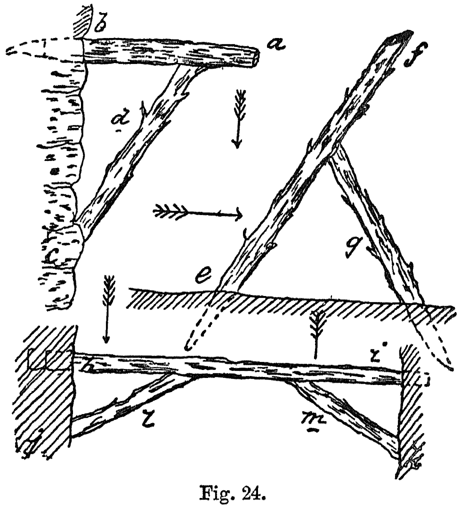

Fig. 24.

of the diagonal member in framing—we show one or two more in fig. 24. The piece *a b*, projecting from the face of a rock or bank of earth, or a wall *b c*, is made capable of resisting greater weight or pressure put upon it by adding the prop *d*, as in like manner the piece *f g* is made capable of resisting pressure by the addition of the prop *g*, and the piece *h i*, which we may suppose to be a trunk of a tree thrown across as a bridge, an opening, or "void," between the two cliffs, as *h j*, *i k*, is strengthened by the two props *l m*.

We have said that the assemblage of timber in fig. 22, at *i j m n*, illustrates all the parts of a modern roof truss of the class known as

a "king post" and "roof," and that this gives the strongest combination of timber. The "pressures" are so "distributed," and are "communicated" or led in such directions, that they are all concentrated, so to say, at the points of greatest resistance. Thus in the case of a simple or rude form of a roof truss, *a b c* (fig. 25), the pressures are thrown upon the walls, *f*, *f*, and consequently an assemblage of timber can be designed which can be thrown across a "void" or opening, as *f f*, as in the case of an assemblage as at *g h i j*, which may represent a partition stretching across the void *k* of an apartment or space. Trusses may be, and are, as we shall

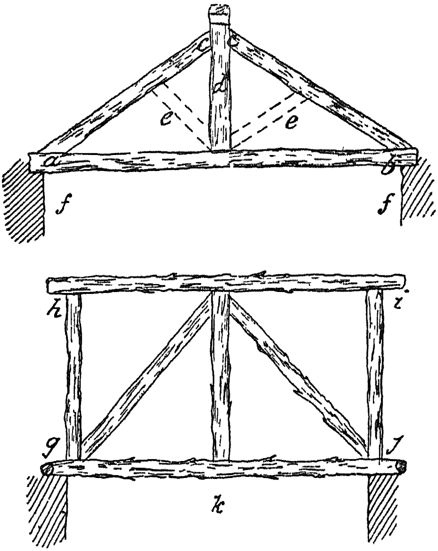

Fig. 25.

see in succeeding illustrations, of various forms; but in all of them, by the use of diagonally placed timbers, triangles are formed.

Technical Terms applied to the Individual Members or Pieces of Timber Framings.

We have called hitherto the piece or member, *c d*, in fig. 22, a prop. This is a popular term for it; but it became, and is still distinguished in technical carpentry phrase, as a "strut" or "brace." The technical name for the member *a b* is still, what we have as yet called it, a "post." Used in a certain way, a post so placed becomes a column, pillar, or standard. The member, as *h i*, in fig. 24, is

called a beam, if of comparatively large section; of the largest, it is termed a "girder."

In a framing thrown across—or "spanning" as the technical phrase is—a void or open space, *f f* (fig. 25), as between two walls, the beam is called specifically a "tie beam." And although inclined, as at *c d*, in fig. 22, the inclined pieces *a c*, *b c* (fig. 25), are not, as in fig. 22, termed struts or braces, but "rafters." In a king-post roof truss, as in fig. 25, at *a b*, *c d*, *e e*, other members placed diagonally supporting the rafters at a certain point in their length are placed as shown at the dotted line *d*. Timbers so placed in a truss are then called struts or braces; the vertical post *c d* is called a "king post."

We trust that the reader who has done us the favour to read the foregoing matter will have obtained not a little information on the strictly technical points of the art of carpentry, and a fair idea of some of the leading principles upon which it is based. This will be all the more clearly perceived as he proceeds to the consideration of the various departments which will form the subjects of succeeding chapters.

Iron used in the Construction of Framing generally considered as belonging to the Work of the Carpenter.—Present and Future Use of Timber in his Construction.

It is scarcely necessary further to allude to the development of the art of carpentry in the later phases of its history. Suffice it to say that up till a comparatively recent period timber was the material employed in the construction of every kind of framing, and that some of the best examples were shown at periods of European history which some are disposed to think were, as they are generally called, the dark or middle ages. Of these ages, however, it may be truly said that they tended at the least to conserve or preserve arts which would otherwise have died out, and their reproducing or re-invention been necessitated. It is only within times comparatively, or, as may with truth be said, absolutely recent, that timber in the construction of a wide variety of framing has been superseded by iron. At first the form or variety of this metal chiefly used was that known as "cast iron." Then followed the superior material, wrought or malleable iron; and this latter, so long used and so valuable, is now being gradually, if not quickly, superseded by steel.

But although those metals have been largely used and are still used for the construction of framing, to the exclusion of timber, the at one time universally employed, and indeed only available material; still there remains, and will, so far as we know, long remain, a wide field for the employment of timber in the large works in which it proves so useful. As a rule, iron and steel are employed only for

the large—in many instances, vast—structures or framework of civil engineering, as bridges, viaducts, in railway work, etc., etc. But for the wide variety of roofs, partition floors, etc., etc., used in civil architecture, as churches and public buildings—and in domestic architecture, as in houses, rural structures, and the like—there is still a wide field for the exercise of the skill of the carpenter, and which will long demand the use of the material in which he works. Even, indeed, in the large structures we have alluded to as coming within the domain of the civil engineer, in which he uses wrought iron or steel, he finds the services of the carpenter, with his timber, absolutely necessary. In this the heavier material possesses many advantages for what may be called the foundation framing or scaffolding by which and upon which he raises his superstructure of iron and steel.

Carpentry, then, still remains an important branch of technical work, for which there will still be a wide field in which those who follow it will be able to display their skill in execution and their ability in design. That this will be so for a long time in our own country is beyond a doubt. The uses to which timber in the large, as contrasted with it in the smaller "scantlings" or sizes used in the sister arts of joinery and cabinet making, can be put are so numerous, and the ease with which it can be adapted to various combinations of design so great, that for long time to come at least carpentry will be one of the most important branches of national industry. But if timber be less used now than it formerly was on the continent of Europe—and it is chiefly in the more gigantic works of the civil engineer that it has been superseded by iron and steel—in the continent of the New World we find it is used on the most extensive scale. Throughout the United States of America, specially, and even in our own great colonial possessions in Canada, not merely do we find it used universally in all works of the architect and builder of civil and domestic structures, but we have an almost endless variety and number of examples of the adaptation of timber to the more gigantic and complicated structures met with in public works, alike on the road, the river, the sea margin, and the railway. If this feature be less marked in our other colonies, such as on the Australian continent and in our colony of New Zealand, and our still more important possessions in India, even there timber is largely used in construction. And this is likely to be the case for long, for timber is abundant to a degree of which those who have not a personal knowledge of those countries have not even the slightest idea. And this work, in the pages of which these chapters on the art of the carpenter's work will appear, although perhaps more especially

designed to meet the wants and wishes of the large and most important body of technical workers in our own island home, nevertheless addresses itself to their brothers in skill and business energy in all countries, however distant, in all our colonies, however remote, in which is spoken and read the "grand old English tongue" in which Shakespeare wrote and Milton sang. So that for these papers of ours we have a wide circle to address, a numerous *clientèle* to cater for. And although as compared with some of the branches of our technical trades and arts, the branch of technical work we in these chapters are now concerned with may not possess all the features of, shall we say, popular interest? still we can safely claim for it that of a special and a truly scientific one second to none. Apart from its practical details, always interesting and suggestive, scientific theories, or rather, as we should say, principles, are concerned and mixed up with it, which in many departments are specially applicable to other branches of technical work in which mechanical construction is a marked, if not the only distinct and special feature. While, therefore, we do not wish to overestimate the importance of the subject of those special chapters, we believe it to possess or carry along with it practical work and scientific considerations of a high value. And if, in addition to those who have a special and direct interest in its operations, as forming the work of their daily lives, we can impart to others who have not merely a general desire to add to their acquirements, but what is called a taste for mechanical work, some interest in the work of carpentry, we shall be abundantly rewarded for such labour as the preparation of our chapters has entailed upon us. It is well when the work we have to do can be claimed as a labour of utility; it adds a fresher zest to that work when it comes under the category of a labour of love.

Varieties of First Class of Joints—Square Joints.

We have in the preceding paragraphs presented some remarks and illustrations connected with the use and cutting up of timber, the representative joints by which pieces are secured one to another, and with the elementary points of framing or of framework. From these the reader will have gleaned some idea of the first principles of the art, and will be prepared now to take up the systematic consideration of its various departments, of which the first will be those of joints, beginning with that illustrated in fig. 1, which we have already given as one of the representative joints. In this the piece *a a* (fig. 1, *ante*), supposed to be lying horizontally, as, say on the ground soil, forms what is technically called a "sill," which is very likely to be a mere corruption of the word sole, or base. This term, further and more

specific illustration of which will be given hereafter, is often spelt as "cill," but if our derivation be correct this is wrong, and the other, and we may say perhaps the more usually adopted mode of spelling the word, with an *s*, is the right one. To the sill *a a* the vertical piece *b* is to be joined. The simplest method of effecting the junction would be merely to rest the end of *b* upon the face of *a a*. In this case its mere weight, on the principle of gravity, or the pressure exerted by any mass of material supported or carried by the timber (*b*), would have to be trusted to to keep the piece *b* in its position as placed in *a a*. This simple method is still often adopted in the practice of the present day, but it is needless to say only in cases where the pressure is great which is exerted on the piece (*b*), and that pressure only in a vertical direction or parallel to the axis of the piece. By the term "axis" of a piece of timber is meant an imaginary line which passes through the centre of the piece. If it were circular the axis would pass through the centre; if the two ends were square or rectangular, through the point of intersection of two diagonal lines drawn from opposite corners of the square or rectangle.

If the simplest of all the methods of joining piece *b* to *a a* above described were adopted, the efficiency of the junction would obviously depend upon the condition in which the two joining surfaces were. If the surface of *a a* at the point or place of junction were uneven, or if this were the case at the surface of the end of *b*, the inequalities of surface would prevent the whole of the two surfaces touching each other. The one piece at *b* would clearly "rock" from side to side exactly as it was moved, and this evil would be all the more pronounced, not merely in proportion to the unevenness of the surface of either one or the other; if both surfaces were unequal. The joint here supposed is one in which the one piece *a b* merely presses against the surface of the other at *a a*; and the piece *b* is said technically to "butt," this term being obviously a corruption or rather a compression or shortening of the term "abutment." The point of junction at *c* is technically called the "seat" of the joint, or the actual place or position which the joint end of the piece occupies in the other.

Analysis of the Foregoing Joint.

To gain the full efficiency of the simple joint at *c*, fig. 1, it is obvious that the "seat" must be such that the whole of the meeting surfaces shall be perfectly straight and flat, or even, in other words, be free from all protuberances, which, existing on any surface, cause of necessity corresponding hollows or depressed parts. Hence a require

ment in all carpentry work where junctions are to be formed between its members—a test of the carpenter's ability as a handicraftsman—is that he makes his joints perfect in surface. When so treated, they are in technical language said to be "well and truly wrought" or worked, although in specifications of work to be done the word wrought is generally employed. But on the supposition that the "seat" *c* of the simple joint now under consideration is correct, or that the two "butting" or meeting surfaces are "well and truly wrought" by the handicraft carpenter, their junction would only be maintained if the pressure on *b* was vertical. Any pressure exerted upon the "foot" of the piece *b* near the seat *c* in the direction indicated by the arrows *d*, *e*, or in an opposite direction, would clearly tend to push the foot of *b* away from the seat, causing it to slide along the surface of *a a*, either to the right from pressure in

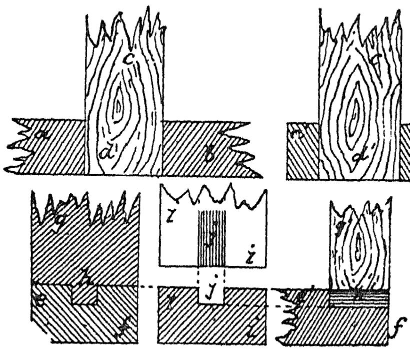

Fig. 26.

direction of arrow *d*, or to the left if much pressed in the opposite direction.

The young reader must not suppose that we are needlessly extending or elaborating our description of this illustration in fig. 1. We are on purpose going fully into it, and before we can finish with it we trust that the pupil will be able to gather from it certain principles of or points in construction which will be of practical utility to him in his more advanced study of the art and science of carpentry, and those being understood by him at this the earliest stage of it, will not have to be repeated by us in illustrating and explaining the various forms of "joints" in use, as these principles affect all combinations. Indeed, it is only by comprehending them thoroughly that the pupil can see the object which a particular joint has in view

—its *raison d'être*, as the French phrase has it—which, truly translated, means its very right to exist or to be.

Still keeping under consideration the simple "butting" joint of the pieces *a a* and *b*, fig 1, *ante*, p. 11, we can conceive that the piece *b* might be subjected to pressure in directions other than those indicated by the arrows *d*, *e*. In *a a* the piece is supposed to be lying on the flat, so that we can only see, when looking at it directly and on the same level, the side or edge of it. This, as in *a a*, is called a "side elevation" in the language of what we may call technical drawing as different from that known as pictorial representation. Let us suppose that we are now looking vertically down upon the piece *a a* from a point above the upper termination of the piece *b*, and in a direction coincident with its axis or central line. If we put on paper a technical view of what we see in thus looking, we have what in architectural and engineering drawing is called a plan of the pieces *a a* and *b*; and this is shown in fig. 1 at *f f*, which is the plan of the piece *a a*, *g* being the end of the piece *b*. To make the distinction between the two pieces more obvious, we have lined or "hatched" the plan of *b*, which gives it in what is called a "section" or "sectional plan." The pupil will from this sketch see how pressure may be exerted upon the foot of *b* in directions other than those indicated by arrows at *d*, *e*, as in that of the arrow *h*.

The next form of joint which we may conceive the early workers to have made is illustrated in fig. 26, it being very likely suggested by their previously well-known experience in fastening vertical posts by simply pressing them into the soft, or digging a hole in hard, soil, inserting in this, and then securing it by means of softer soil rammed round it, or by putting in stones to act as wedges. In process of time it would be required in some work that a piece lying horizontally (*a b*, fig. 26) should support a vertical piece (*e d*). A hole, either rectangular or square, as at *o o* in the piece in fig. 1, p. 11, vol. i., would be cut in the piece *a b*, and the end of *e d*, fig. 26, simply passed into it, as shown in the section to the right at top of figure. It might have been desirable to have the piece *g* penetrating as little as possible into the piece *e f*, or to have avoided cutting too much out of *e f*, as shown at *a b*, and thus weakening it; this would be done by cutting the end of piece *g* so as to leave a projecting part, as at *h*, right across the breadth of the piece. By cutting a groove near the end of the piece *e f*, as shown in the plan at *j* in *i i*, and in the lower diagram in section, the piece *g* could be slipped with its projection *h* into the groove, as shown in longitudinal section to the right of the lower part of diagram at *g′ h′ f*.

Simplest Form of the Mortise and Tenon Joint.

This would be the origin of the "mortise and tenon joint," of which we give an illustration in front and side elevation in fig. 27, and in details in fig. 28. In fig. 27 *a b c d* shows the lower or

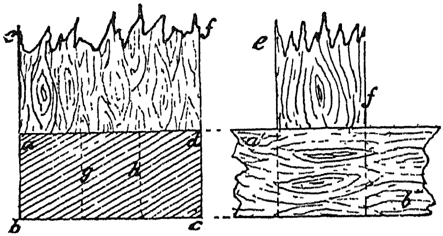

Fig. 27.

horizontal piece in section or end view, with the upper or vertical piece *e f* joined to it by the projecting piece at the end of the piece *e f* going into a slot or hole cut in the piece *a b c d*—*g h* giving the

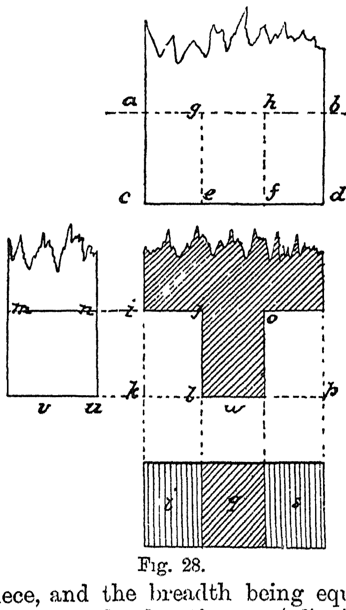

Fig. 28.

thickness of the piece, and the breadth being equal to the breadth of the piece so shown in side elevation at *e′ f′*, *a′ b′* being side view of piece *a b c d*. The part *g h*, cut at the end of the piece *e f*, is

called the "tenon"; the aperture made in the piece *a b c d* is called the "mortise" or "mortice." The depth of the "tenon," as *l j*, fig. 28, is generally equal to the depth of the piece, as *a b c d*, to which it is joined, and the thickness or width of the "tenon," as *j o*, is, when well proportioned, about one-third of the width of the piece. *j l w o* shows a side view of the piece of which *m n u t* is the edge view, *i q s* being the plan of the end of "tenon" as it is looked vertically down upon.

Practical Points connected with the "Mortise and Tenon" Joint.

The mortise aperture, or hole cut in the lower piece or member, should be of the shape and of the dimensions of the tenon formed at the end of the upper piece, which is to fill it without leaving any space round it. The thickness of the tenon should be equal, as we have said, to the third of that of the piece of wood into which it is put, in order that it may have sufficient strength, and that the piece out of which is hollowed the mortise into which the tenon must enter may not be too much weakened by any considerable loss of wood. The depth of the mortise, which should be equal to the length of the tenon, is generally two-thirds of the thickness of the piece out of which it must be cut; in any case, it should not exceed three-quarters of this thickness, above all when the piece which bears the tenon is to be placed upright. The illustration fig. 28 shows a frequent exception to this, as the mortise goes right through the thickness of the piece. The object of leaving a part of the piece uncut in the lower member *a b c d*, fig. 27, is to give a good butting sound joint to the end, as *w*, of the tenon. The parts *i j* and *o*, which are on each side of a mortise, fig. 28, and which should have, like the mortise, the third of the thickness of the piece of wood, are called the "shoulders" of the tenon. When the tenon is sunk or driven into the mortise, the shoulders (as *i j*, fig. 28) of the tenon should touch the face or cheeks of the mortise; the pieces are then fastened by one or two wooden or iron pins—generally wooden. These bolts should be placed so as to penetrate the cheeks and the tenon, passing through the middle of the length of the latter. If one does not wish to put in two pins or trenails, we divide the width of the tenon into three equal parts, to retain sufficient space of solid wood round the pinholes, and so secure for the tenon the greatest amount of strength.

This joint has all the necessary solidity only when the tenon is driven forcibly into the mortise. When the tenon works loose in the mortise the joint is very soon destroyed by the strain to which it is of necessity subjected. It is obvious that the pins which help

to keep together a joint add nothing to its solidity. To make this joint, we commence by drawing carefully on the two pieces which are to be joined lines which shall determine the shape of the tenon and the mortise, so that we may take away only the useless wood, and succeed in easily making the tenon and the mortise of equal sizes, and perfectly true to one another—the latter in the form of a hollow or part cut out, the former (the tenon) as a projection. We shall now point out the way in which this outline is to be made, commencing with the tenon:—Let *a b c d*, etc., fig. 28, be the piece which is to have the tenon cut on it: draw, at a distance from the end of piece equal to the length of the tenon, a line *a b* parallel to *c d*: divide *a b* or *c d* into three equal parts in points *g h*, taken on the width of the piece (that in the middle, as *g h*, *e f* being reserved for the tenon) with a saw, and following the line *a b*, cut the wood to *g*. Do the same on the surface *b h*, cutting to *h*; cut away the pieces *a g e c* and *f h b d* by sawing on the lines *e g f h*, and we thus form the tenon.

Cutting out of Double Tenon—Cutting out of Mortise.

To form a double tenon, divide the width *b c* (fig. 2, *ante*) of the piece of wood into five equal parts—*c g h i j f*—instead of three, as in fig. 28, and give one of these five parts to each of the tenons, as *g h i j*, taking or sawing away the two outside parts, as *c b f c*, similar to those of the simple tenons. Next cutting out the central part *h i*, we form two projecting parts, each of which is a tenon on the end of the piece *a e f d*, as shown in cross section at *v w*. The plan or upper face of the lower piece, in which the mortises are cut, is at *m n*; the lines giving the breadth, as *s r n p*, of this being taken down from the side elevation, as shown by dotted lines from points, as *k l*. The length of the mortise, as *o n* or *p q*, is, of course, equal to the thickness of the piece, as *g*, bearing the tenons, as at *t u*, which is a side view of tenon; *x x* being part longitudinal section though tenon and mortise.

The cutting out of a central part, as *h i*, fig. 2, *ante*, to form the void space, as between the two tenons *v* and *w*, cannot be done wholly with the tenon saw, as at the line *h i*. The lines, as *i k*, are first sawn down to the points *h* and *i*, and then holes are bored with the "brace and bit," as at *r*, *s*, fig. 29. These holes go through the whole piece, so that by striking the piece with the hammer or the mallet it can be easily detached, as there is but very little solid wood between the holes *r*, *s*, fig. 30. There then remains nothing but to square or face up the sawn or rough surfaces of the two tenons, as *v* and *w*, fig. 2, *ante*.

In making a mortise when the tenon is already made, we commence by making fast the piece of wood in which we wish to cut out the mortise, and if the tenon, should be in the middle of the piece—*i.e.*, a single tenon, as at *w*, fig. 28—we trace a line, *b m*, fig. 29, at equal distance from the two arrises or edges, *h* and *i*; we take then the half of the thickness of the tenon, which we set off on each side of the centre line *h g i* to points *l* and *m*, and we draw parallel to *b m* two lines, as at *h* and *i*. We then take the width of the tenon, and set it off from central point *g* to *h* and *i*, carry it between these two lines, and thus have exactly the size of mortise hole. If, instead of being in the middle of the piece of wood, the mortise hole should be carried more to one side than another, we must commence by drawing a line which shall fix the position of the tenon, taking its thickness and drawing it at the side of this line—for, in carrying this width between these two lines, we shall get the exact place for the tenon.

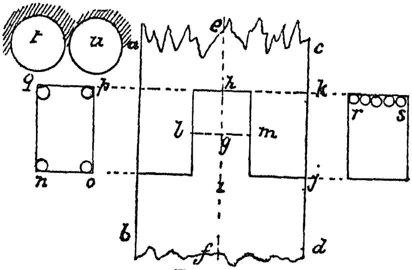

Fig. 29

The position and size of the mortise being outlined as above, to form the hollow or cut-out part, next pierce holes at each of the corners, as *n*, *o*, *p*, *q*, fig. 29, and then connect these by a row of holes as at *r s*, or at *t u*, and the small widths of solid stuff between the holes can be cut through with the chisel, or divided by using the narrow, thin-bladed saw, used for cutting out keyholes, called the "fret saw." This may also be used to cut out the solid part in the centre of the mortise, as the part *n o p q*, fig. 29, connecting the holes at the four corners made by the brace and bit.

If the tenon were double we should require to draw also two mortises near each other bearing exactly the breadth and the thickness of each tenon. These two mortises would be made separately and in the same way as ordinary mortises. This joint has everywhere the same thickness, but the pieces which bear the tenons are not always placed vertically or perpendicularly; often, as in floors, they must be

placed horizontally. In this position, the tenons being placed on the flat side only, all strain is supported by their thickness; then, to give to the tenon greater solidity, it is strengthened by a small canting or sloping shoulder which joins the piece to the tenon.

Mortise and Tenon Joints—Forms other than those already Illustrated.

In fig. 3, *ante*, we give a drawing illustrative of a mortise and tenon joint at which one piece, *b b*, receives at its end another piece *a e b*, as shown in section at *h*. The tenon in this case is not square or rectangular, as in the other and preceding examples given, but is of the form known as the "dovetail," as at *e*; this is cut at the end *e* of the piece *a a*, which corresponds to *h* in form and size.

Fig. 30 illustrates a mortise and tenon joint in which the face of

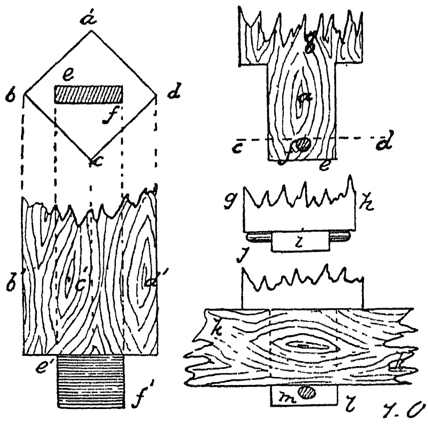

Fig 30

the one piece, as *a b c d*, is oblique to the face of the other piece, of which the mortise hole is shown at *e f*. The drawing immediately below is a view of the side *b c d*, and *e f* the front face of the tenon. When the tenon of one piece, as *a*, passes right through the mortise made in the other piece, as *k k*, the tenon is made long enough to leave a piece, as *i*, projecting from the under side of the other piece having the mortise cut in it; a hole, as *f*, is bored through the projection from side to side, as at *i*, and a pin *j* drawn in tightly through it, thus keeping the tenon in the mortise, as shown.

Another method is shown in fig. 31, in which the tenon *b* at the end of one piece, *a a*, is flat and rectangular in section, and of same breadth throughout, but the mortise in the other piece *c c*, to which

a a is to be joined, is of the dovetail form, in which the narrow end or neck is at *d*, the base at *e e*, plan of this at bottom or lower edge of *c c*, as shown at *g* in edge view *f f*; *b' b' a'* is side or edge view of tenon *b* and piece *a a*; the tenon, as *m*, of piece *k k* is passed into the mortise, as at *l l*; and wedges are driven up, as at *o n*. The shape

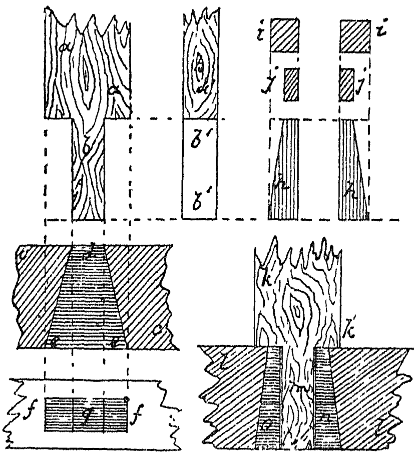

Fig. 31.

of those wedges is shown at *h h* in side elevation; section of the narrow end at *j j*, and of the width at *i i*.

Another modification of this joint, with dovetail mortise and rectangular tenon, is shown in fig. 32, and is known as the foxtail dovetail mortise and tenon. In this the mortise is a dead mortise—

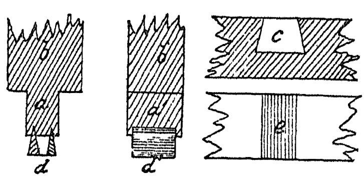

Fig 32

that is, it is not cut through from surface to surface of the piece, but stops short, as at *c*, *e* being plan of neck or narrow part of the mortise which cuts across the whole breadth of face or edge of piece as shown The tenon *a* on piece *b* is sawn across to a certain depth at its end, in two places, and into these saw draughts wedges, as *d*,

are inserted. The whole are then forced into the mortise *c*, and driven up; and this causing the wedges pressing in the bottom, *c*, of the mortise, to be forced up into the tenon *a*, the sides of this are forced out laterally so as to fill up the spaces on each side. *a' b' d'* is an edge view of *b d*.

Fig. 12 illustrates the application of the mortise and tenon joint to the junction of a "king post" foot with a "tie beam" (for these terms see paragraphs on Roofs). In this *a* is the king post, *b* the tie beam. The foot of the king post *a* is provided with a tenon, *c*, which goes into a mortise, *e*, cut in the upper edge of the beam. The termination of what are called the "struts" or "braces" are shown at *d e*; these being mortised into the sloping, butting surfaces at foot and on each side of the king post, *b* being the tenon. The mortise is shown in side view at *f*.

The application of the tenon and mortise to the junction of the foot of a "queen post" (see paragraphs on Roofs) with the "tie beam," is shown in fig. 6, in which *a* is the queen post, *b b* the tie beam, *c c* the tenon formed at foot of the queen post; this being seamed by the wedge *d d*; *e* is end of a strut. The diagram to the right of same figure shows termination of end of the queen post of a single queen-post roof (see paragraphs on Roofs). In this diagram *f f* is part of the tie beam, *g g* of the foot of queen post, with its tenon *h* shown in dotted lines with wedge *i i*; *j* is part of the straining sill, *k* end of "strut" or "brace," with tenon *l* let into mortise in the butting face of queen post.

Joints used in Pieces both of which are Vertical in the Same Line.—Practical Points connected with this Class of Joints.

The joints used in forming a connection or junction between two pieces of timber, already illustrated, are all used where one of the pieces is vertical, and rests upon the other piece which is horizontal. We now illustrate joints used for the junction of two pieces both of which are vertical. This class may be looked upon as giving joints for extending the length or height of vertical pieces. Under certain circumstances the joints now to be illustrated under this head may be used in the junction of two pieces which are placed horizontally. But in such a use of them they are placed under strains which the joints are not the best calculated to resist, unless the pieces rest upon other pieces, or upon points of a building which give a solid support, if not through the whole of their length, at least for some distance on both sides of the joint. If the two pieces joined by any of the methods now to be considered and illustrated are used in circumstances other than this now named, such as the stretching over—

technically called the "spanning"—of a void space, the joints are placed under severe strain, for which they are, as a rule, not calculated. Joints for this class of work are specially designed, and will in their place be considered. We proceed, therefore, to describe and illustrate the joints which are strictly those for use in lengthening out of a vertical piece by joining another vertical piece to it.

In fig. 33 we give an illustration showing the principle of the method in work of this class; it shows also the simplest form of joint used in it. The object in view is to keep the ends of the two pieces from sliding or being pressed out of contact with each other. If the end of each piece be simply squared off, and made perfectly flat—and this preparative method is necessary in all joints of this kind—the two may be kept in contact with each other merely by the dead weight of the upper piece, or by any weight pressing upon its upper extremity or top. But this contact is obviously dependent upon the stability of the two pieces If either one piece or the other, as the top or the bottom piece, or both of them, be subjected to pressure calculated to cause it, or both, to get out of the line of stability, it is obvious that the one may be pressed more or less, or completely, out of contact with the other. Now, perfect stability depends upon the maintenance of the true vertical line of the two posts or pieces—that is, upon the two being what is technically called "plumb" (see the volume entitled "The Geometrical Draughtsman" for a description of what constitutes a vertical or "plumb" line, and what constitutes the difference between a line of this sort and a perpendicular—which may be two perfectly distinct and separate things, though often, and we may indeed say popularly, believed to be one and the same thing). Now, this retention of the strictly accurate plumb line in posts or pieces of timber plumb vertically is liable in all framework to be more or less dangerously influenced, and this by pressures or strains thrown upon the timber. The mere insecurity of the foundation on which the lower timbers rest may induce an unequal settlement, which will throw it "out of the plumb" or away from the vertical direction.

A side or lateral strain may from one cause or another be brought to bear upon the timber near to, or directly at, the "seat" of the joint which we are supposing to be formed by mere contact of flat surfaces square or at right angles to the length of face of the timbers, which pressure would rapidly tend to separate the two pieces. As we shall see in a future chapter, when we come to treat of the principles of framing, all framework is designed so that it shall remain perfectly stable—that is, that it shall retain the original form after due settlement or final adjustment of the parts. For when any

disturbing element is not provided for, and strains or pressures allowed to act, causing even but a slight change in any one joint, as the whole parts are joined or connected together, this change may be communicated to another part, causing a change from its normal or safe condition; and as those changes set in in rapidly increasing ratio or proportion, a slight change at one part of the framing may cause a much greater change in a more remote and perhaps more vital part, and destruction of the whole may be the result. It is

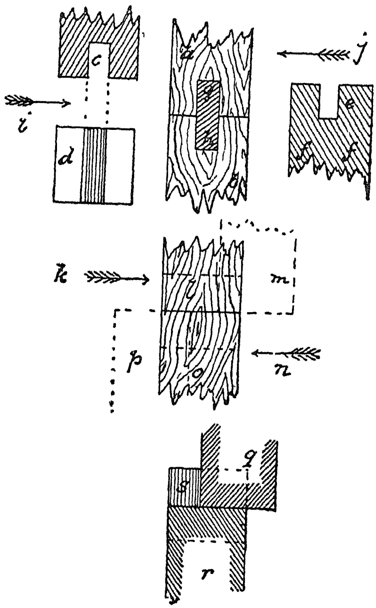

Fig. 33

surprising how rapidly the total collapse of a framing follows upon the first change of a part of it from the true, stable or safe position. A crack or crink is heard, and fortunate are they who under framing hear it in time to get clear from under or off the falling mass. Joints of vertical timbers are therefore rarely made with merely squared surfaces in contact, unless in cases where the timbers are heavy and subject almost wholly to vertical pressures, lateral ones being very unlikely to come into play. But even in such joints with simple contact they often are, or should for safety be, provided with side

plates of iron, or bound round with an iron hoop or strap securely fastened.

Illustration of the Foregoing Principles of this Class of Vertical Joints.

In fig. 33 the simplest form of joint of the class now under consideration is illustrated. In this the end of each piece, that of *a* and *b*, are provided with grooves, as at *e*, shown in the section of the lowest of the pieces at *f f*, and at *c* at the upper; these grooves are ploughed or cut out across the face of end and from side to side, as shown at *l*; and when the two pieces are placed with their end surfaces in contact, a groove or rather slotted opening is thus formed of such depth that a flat wedge or "key" of wood or of iron can be inserted, as at *g h*, the depth of which is twice that of the groove made at the end of each piece, as at *c* or *e*. When so placed

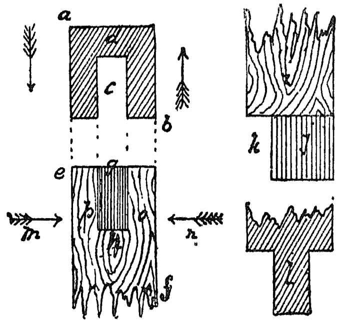

Fig. 34.

and secured together it will be obvious that the lower piece, as *b*, may be so securely fixed at its foundation, or at its lower part, that it can resist any tendency it has, or which may be put upon it by pressure, to swerve from the plumb line. The "key" *g h* prevents any pressure acting in the direction of the arrow *i* or *j* from affecting the upper pieces and the joint remaining good. But this is because the pressure is acting against the flat or broadest surface of the "key" *g h*. But if the pressure acted upon the other side of the piece, as in the direction of the end of the key, as shown by the arrows *k* and *m*, there would be nothing to prevent the one piece, as *l*, being removed or caused to slide away from the other piece, *o*, in the direction of the dotted part *m*. Just as would be the case in the event of the pressure being applied in the direction of the arrow *n*, which would give the tendency of the piece *o* to slide away from the

as *k*, is framed at the end of the piece; *k l* shown in view is section of the other side of the piece, with the edge of the tenon at *l*. While the "key" *g h*, in fig. 33, provided for only two directions of actual pressure, as understood by the arrows *i* and *j*, it did not provide for the other two directions, four in all, there being four sides to the posts or pieces shown at arrows *k* and *n*. But in the arrangement in fig. 34 three actual pressures, tending to cause the pieces to slide away from contact with each other, out of the four are provided for; the outer ones, *m* and *n*, corresponding to *i* and *j*, fig. 33, being provided for in both cases equally; but the end corresponding to *k* or *n* in fig. 33 is met by giving a solid back (*d*) to the groove *c*, fig. 34, against which the edge *k* of the tenon *j* butts or presses, so that all sliding is prevented in the direction of the

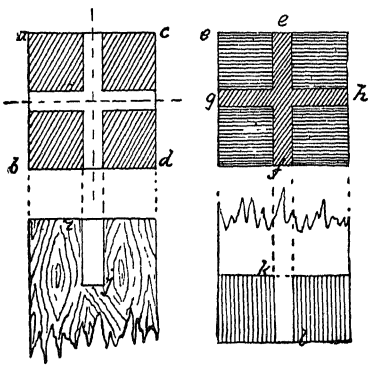

Fig. 36.

arrow *b*, or that to the right hand—the only direction of sliding pressure not provided for being that acting in the direction of the arrow to the left hand of *a*, forcing the tenon out of the mortise, which may be prevented by passing a pin or trenail through piece *a b* and tenon *j*, as from side *a* to side *e*.

In fig. 35 we illustrate another form of joint of this class, in which the four actual pressures tending to cause a sliding away action of the two faces of the posts, upper and lower, are provided against. In this *a b c d* shows the end of the upper face of lower post, in which two grooves on the central lines, *e h*, *f i*, are cut, as *g h*, on line *e h*, being at right angles to the other, as *i g*, on line *i f*, a side elevation of the groove *h* being shown at *j*. On the lower face of the upper post, *k l*, two tenons, as at *m n*, are cut at right angles, as shown. These go into the grooves or open mortises *h i*,

and, it will be seen, provide against the pressures arising from directions as shown by arrows 1 and 2, and from those opposite to these. A more equally distributed form of this last principle of joint is shown in fig. 36, in which grooves running from face *a b* to face *c d* of the post in opposite directions, and from face *b d* to face *a c*, forming a cross, and cut in the upper face of the lower post; while

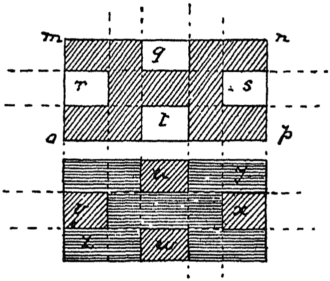

Fig. 37.

four tenons, forming also a cross, are cut, as at *e f g h*, on the lower face of the upper post, these passing into the grooves, as *a b c d*. A side view of lower post at top, with groove *i j*, is shown, as also a like view of upper post at foot at *k l*. Fig. 37 illustrates another way of forming the joint so as to meet the pressures in all directions. In this the part *m n o p* is plan of upper side of lower piece, having

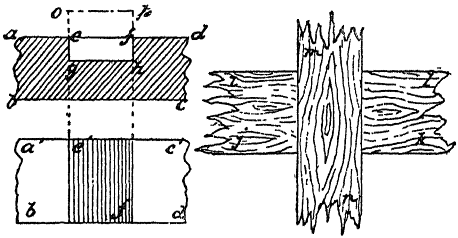

Fig. 38.

parts, or what may be called open mortises, cut out, as shown at *q*, *r*, *s*, and *t*, these being of depth equal to the length of the tenons or projecting parts cut in the lower end of upper part. Plan of this is shown in the lower diagram: *u*, *v*, *w*, and *x* show the ends of the tenons, and the parts between them, as *y* and *z*, being cut away to the same depth, thus leaving parts *u v w x* projecting from the end, and which pass into the open mortises *q*, *r*, *s*, and *t*.

Horizontal Joints used in Pieces crossing at Right Angles.

We now come to the third class of joints, used in connecting horizontal pieces crossing each other or meeting at right angles. The simplest form of this joint would obviously be by laying the one piece, as the upper, *m n*, in fig. 38, upon the other and lower piece, as *i j k l*, and securing the two by wooden trenails or pins, or by nails or screw-nails. This, for small work on which no great strain is put, would give a joint fairly secure.

In more perfect work, however, the joint is made in the way shown to the left of fig. 38: in the lower piece, *a b c d*, a groove, as *e f g h*, is cut right across, and of a depth, as in *e f*, in proportion to the thickness of the upper piece, as *g o p h*. The plan of the lower piece, with groove, as *e′ f′*, is shown at *a′ b′ c′ d′*. The upper piece, as shown by the partly-dotted lines, as *g o p h*, is passed into the groove as *e′ f′*, which is made a little less than the section of the piece, as *m n*, so that it requires to be driven tightly into the groove. No joint is perfect which is loose and admits of any "play" between the parts.

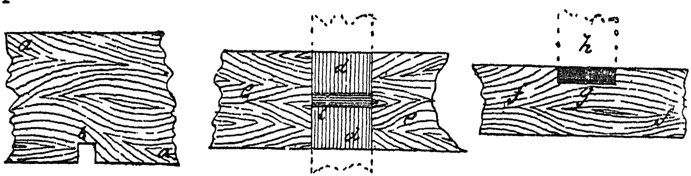

Fig. 39

In fig 39 another form of joint in this class is illustrated. In this a groove or slot, as *b*, is cut across the lower edge of the upper piece *a a*, or a groove *d d* is cut in the upper face of the lower piece, as *e e*, of width enough to admit tightly the edge of upper piece *b b*, the one, as *a a*, going into the groove of the other, as *e e*, in the manner shown at *g h* in *f f*, which is a side view of the assemblage corresponding to *e e* in plan, *h* to *a a* in end view *g*, showing the depth to which the piece *f f* encloses *h*. But in place of the groove in lower piece *e e* being cut out with a level base or floor face, there is a projecting part, as *c*, left in the centre of the face of groove *d d*. The height of this, or its projection from face to groove, is equal to the depth, *b*, of the groove cut in the lower edge of upper piece, *a*. This projection *c* goes into *b*, and the young carpenter will see that the sides or cheeks of the groove in *e e* prevent the piece, as *d d* or *a a*, from being moved in the groove in the direction of its length.

In fig. 5 we illustrated another form of joint of this class, used in

connecting a flooring joist, as *a a* or *c c*, to a "sleeper," as *d*, which rests on the wall *e e*, a groove, as *b*, being cut in the lower edge of the flooring joist *a a* (or *c c*), of width a little less than that of sleeper *d*, this being passed on to *d* keeps the joint *a a* in position.

In place of the groove being cut in the joint it is sometimes cut in the upper edge or face of the sleeper *b b*, fig. 40, and the joists, as *a a*, are let into this.

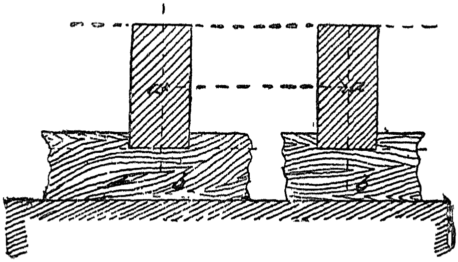

Fig. 40.

Fig. 4 illustrates another joint of this class, as used to connect the „ tie beam" *a a* of roof truss (see further on in illustrations and descriptions of Roofs) which is connected with the wall plate *b*, built into the wall *c c*. A groove is cut in the under side of "tie beam" of sufficient width to embrace tightly the wall plate, as at *b* in fig. 4;

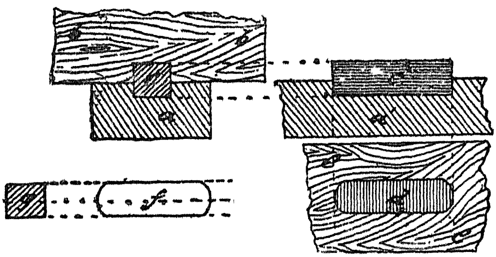

Fig. 41.

or there is a groove cut in the face of the wall plate sufficiently deep to receive half of a key *b*, or in plan at *d*, leaving the other half to project from its face. This other half goes into a corresponding wide groove cut in the lower edge of the "tie beam," and the key, as *d*, keeps the two in contact. Fig. 41 shows a joint more in detail: *a* is the wall plate, *b b* the tie beam, with key *c*; *a′* is side view of wall

plate, *c′* of key, *e e* being plan of wall plate with mortise *d* cut in its face to receive key, of which *f* is a side view and *g* an end or cross section.

The same kind of joint described in fig. 38 is used to connect ceiling joists (see further on for illustrations of floors), as *a*, with the "binding joists" or "binders" *b*; if a double floor, the ceiling joists, as *a a*, carrying the lath and plaster of the ceiling, as shown at *e e*. Fig. 43 shows how a piece is cut out, as at *a*, across the under face in edge of binding joist *b b*, to receive the ceiling joists, as *a a*, in

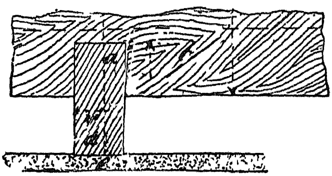

Fig 42.

fig. 42; *c c* is plan of groove or cut *a* in piece, *d d* the plan of lowes edge of binder *b b*.

Joining of Two Horizontal Pieces one at Right Angles to the Other.

Proceeding with our illustrations of joints used in carpentry, we now take up those in classes not hitherto glanced at. In fig. 44 we illustrate the method of joining two horizontal pieces, one of which, as *a a*, is at right angles to the other, as at *b*. In place of merely inserting the piece *a* into a groove or chase cut under the upper side

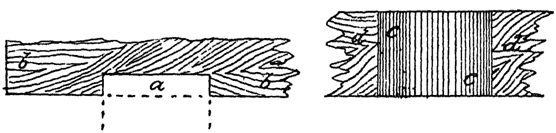

Fig 43

of the face of piece *b b*, and sufficiently wide to admit the piece *a* when drawn tightly into it, the groove does not go right across, but is intercepted, so to say, by a feather shown at *c*, end view of groove being at *d*. The end of the piece *a a* has a groove or chase cut out in its lower edge, as at *e*, at a point sufficiently far from its end to allow the feather *c* to pass into it. The piece *a a* by this arrangement is so secured to the piece *b b* that it cannot be moxed laterally, being restrained by the sides or cheeks of the cross groove, and motion in the direction of its length being prevented by the feather *c*.

The Use of the "Dovetail" and "Wedges" in the Preceding Joint.

Wedges are sometimes used to prevent movement in those directions, as also the form of joint known as the dovetail; those two methods are illustrated in the lower part of fig. 44. The dovetail joint completed is shown at *g g*, *h* being detail in plan of the groove cut out in the face of upper side of the piece, *i* being edge view, and into which the end of *g g* cut with corresponding shape is inserted or drawn in tightly. When wedges or tapered keys, as *e k l*, are used to keep

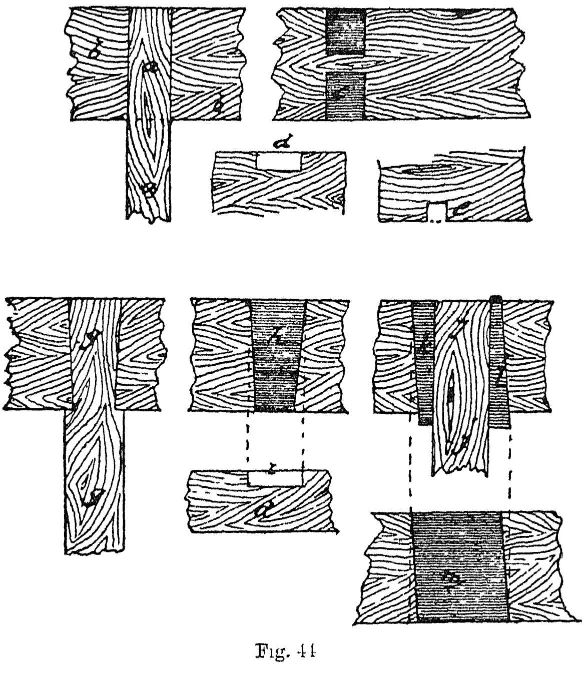

Fig. 44

the piece from moving, as *g g*, the groove is cut of the form as at *m*.

In this joint there is no alteration made in the form of the end of the piece *j j*, as at *g g*; it is left square, but the shape of part cut out, as at *m n*, admits of spaces being left at each side of the piece *j j*, when placed in it, for the wedges *k* and *l* being driven hard up, it will be seen that they are entered from opposite sides, so that by giving corresponding blows to each wedge, as *k* and *l*, a uniform pressure is placed upon the piece *j j*.

Fig. 45 illustrates a joint in which a vertical piece, as *h*, is joined to a horizontal piece, as *l*, but at the extreme end *a a* shows the upper face of the piece *l*, having a part cut out, as at *b*, shown in end elevation at *c*. *f f* shows the side view of end of vertical piece *h*, and *d e g* the end view of the two pieces as joined. Fig. 46 illustrates method of joining a vertical piece, as *b b*, to a horizontal piece, as at

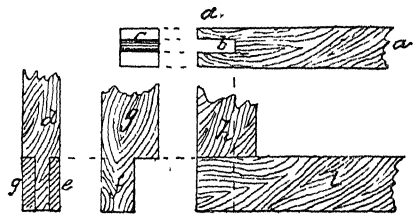

Fig 45.

a a, and at its extreme end; the end of vertical piece being mortised into the horizontal piece.

Joining of a Horizontal with a Vertical Piece.

In fig. 5 we illustrate a joint in which a horizontal piece, *b*, is secured to the face of a vertical strut *a a* in the manner shown at *d e f g*; *d* shows the piece cut out in the strut *a a*. This may be cut right across the face of *a a*, but if so there is nothing to prevent

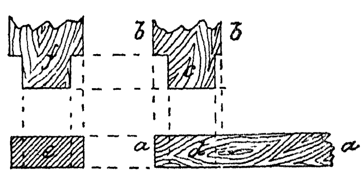

Fig 16.

the piece *b* from being pushed laterally out of connection with *a a*. To prevent this a rib is left in the centre of the part cut out of face *a a* at *d*. This rib goes into a groove cut out of the end of the piece *b*. In place of a rib being left in the face of the part cut out at *d*, the mortise hole, as *g*, is made; into this a tenon left at end of piece *b*, as shown at *h*, is driven. Other views of the piece *h* are shown at *k k l* and *m n*.

Another Method of Joining a Horizontal with a Vertical Piece.

In fig. 47 is illustrated a method of joining a horizontal piece, *g h*, to a vertical piece, *h*. The front view of vertical piece is shown at *a b*; a groove, *c*, is cut across this, in which the part *h* of horizontal piece *g* is placed. A part, as at *j k*, may be cut across the face of vertical piece, the end of horizontal piece being formed to suit this; or the joint shown at *r r q* may be used. In this the face of the vertical piece is broader than the thickness of the horizontal, a mortise being cut in the face of it, as at *p p*, and this provided with a second mortise, *o*, into which the tenon, *q*, of horizontal piece fits, the end going into *p p*. The ends or inner faces of *p p* and *o* are not parallel to the sides of the vertical piece, but oblique, as shown in vertical section at *l m* or *n*. Fig. 3, *ante*, shows another method of

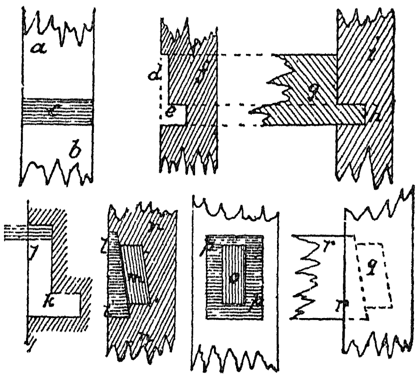

Fig. 47.

joining a horizontal piece, *a a*, as at *e*; or a square tenon may be used, as indicated by the dotted lines joining *e* in *d d* with *e* in *b b*. *f g* shows edge view of piece *a a*, *g* being the tenon *e* in *b b*. Where the dovetail tenon is used, as at *e*, the mortise, in place of being plain, as at *h*, may have two shoulders, as at *k k*, against which the parts *j j* abut.

Joining Two Horizontal Pieces, one of which—a Ceiling Joist—is at Right Angles to the other, as a Bridging Joist, in Flooring.

In fig. 48 we illustrate the methods of joining pieces at right angles, as the "ceiling joists," *e f*, to the "bridging joists" of a floor, as *b b* (see succeeding paragraphs on Floors). The simplest method is by cutting a notch, as *a*, in the lower edge of the bridging joist *b b*, this going right across the face, as shown in plan to the left of *b b*. The

notch is cut of such a width that it embraces the ceiling joists tightly when this is driven up. The joist is indicated by the dotted lines. Other methods are shown at *c* and *d* of finishing the ends of the ceiling joists *e* and *f*; notches, as *e*, being cut in the bridging joists to receive the tongue of projecting parts at *c* and *d*.

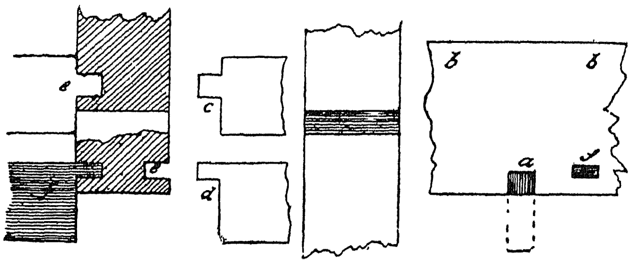

Fig 48.

Junction of One Horizontal Piece, as in a Bridging Joist, to the Vertical or Another Horizontal Piece, as a Beam or Girder in Flooring.

The junction of pieces at right angles, where the end of one piece is secured to the vertical face of the other piece, as *b* and *f* in last figure, is illustrated in the junction of bridging joists, *a*, fig. 49, with the large beam or girder *b* in a double-framed floor (see succeeding paragraphs on Floors). The face of the girder has parts cut out at intervals corresponding to the distances between the bridging joists, as at *g*, the end of joists *a a* being shaped to correspond. The width of the part cut out in face of the girders is equal to the thickness of the joists *a a*, as shown at *e* in face *d* of the girder. In the figure *e* is end or cross section of a flooring joist, the ceiling joists being placed immediately below it. In some cases the end of the joist is cut so as to finish with a long projecting piece, tenon or tail; this passes through a mortise hole in the girder at back, and the two

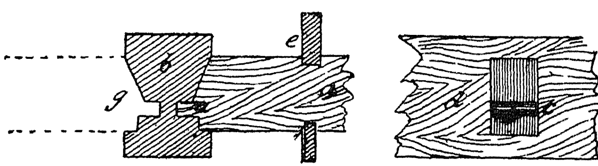

Fig 49

are secured together by a wedge, as shown in fig. 50. When the junction is made as in fig. 49, the end of joist being merely let into the face of the girder, the joist is not so secure as that shown in fig. 50.

Junction of a Horizontal Piece, with an Inclined or Angular Piece.

In fig. 6 a joint is illustrated in which one piece, as *a a*, crosses horizontally an inclined piece, as *b b*. The simplest way of making this joint is cutting out a recessed portion, or a chase, as *d*, in the outer face of piece *b b*. The depth of this being half the thickness of the piece *a a*, when this is forced into the part *d* half the thickness of *a a* projects above the face of *b b*. When the two faces, that of *a a* and that of *b b*, are required to be flush with each other, a part of shape corresponding to the angle *d* is cut also out of the (inner) face of *a a*, half the thickness of the piece in depth. This is shown in

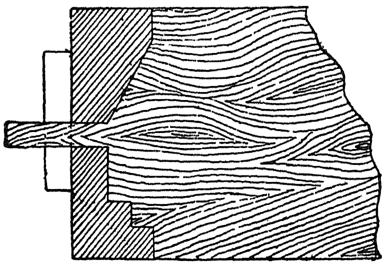

Fig 50.

elevation at *c* and in section at *f*. The most perfect and secure of this kind is where the part, as *d*, is not cut out right across the face of piece, as *b b*, but a rib, feather, or projecting part *h*, as at *g g*, is left in the centre. This fits into a recess or hollow part in the inner face of piece *a a*, so that lateral movement is prevented.

Another Example of Preceding Joint

Fig. 8, *ante*, illustrates a joint of the same class as the last, in which one piece, as *i i*, crosses another, *k k*, at an angle, but in which the joint is not straight-lined, as at *a a*, *b b*, fig. 6, but is cut out with angular knees, as shown at *i i*. Another form of angular joint of this class is shown at *g h*, crossing the piece *f*, the shaded part *g* showing the recess or mortised part cut out in face of *f*. The diagram at top of this, fig. 8, *ante*, shows a form of joint in which the piece *c* joins the piece *d d* at an angle; but does not extend or go beyond the furthest or off side, as at *i i* in same figure. The part cut out of piece *a a* corresponding to *d d* is shown at *b*, with edge view at *c*.

Junction of Two Pieces Crossing Angularly.

Fig. 51 illustrates another class of joint, in which two pieces, *a a*, *b b*, cross each other, both pieces being placed angularly: *c c* shows the face of one piece, as *b b*, with part cut out to receive *a a*. One form of the joint is shown in section, *d e f* being a recess cut out of

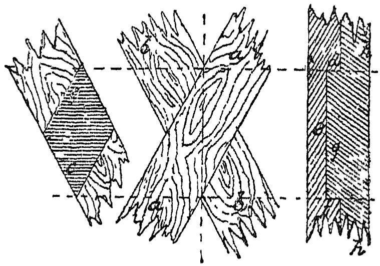

Fig 51.

part, *g* being a correspondingly projecting part left in the centre of the other piece. The usual and the simplest way is to make the same kind of recessed or cut-out part in end, as shown at *c c*; this being cut out to half the depth of the piece, so that when the two are put together, the one going mutually into the other, the faces of the two pieces are flush with each other, like a "half-lap" joint.

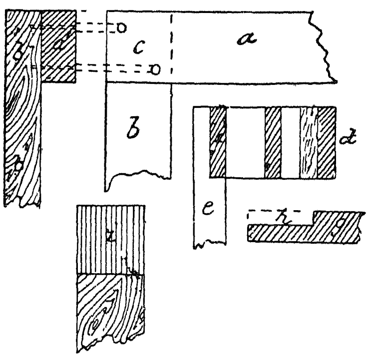

Fig 52.

Pieces joined at Right Angles to Each Other.

In fig. 52 the simplest way of joining two pieces at right angles, as the piece *a* to *b*, the end of piece *a* stopping short at or being cut off or left flush with edge of piece *b*, is by placing the piece *a* on face *b* and securing them with nails. A neater and more secure joint of

this class is made by cutting out a piece, as *i*, in the face of the piece *b b* at its upper end, shown in section at *e f*; a corresponding part is cut out at the end of *a*, as at *h* in *g*; the two when placed together are then flush on the surface. In joints of this class the mitre joint, as in fig. 53, is the neatest The simplest way of making the joint is by cutting the ends of the pieces, as at *a b c d*, those lines being at angle of 45°, as shown by the dotted lines which show the parts cut off. When the two pieces are brought together the joint shows as at *e g*, the one piece at *e f* being exactly at right angles to the other piece *e e*. The pieces when meeting are secured by trenails or nails. The neatest joint of this kind is, however, made by the mortise and

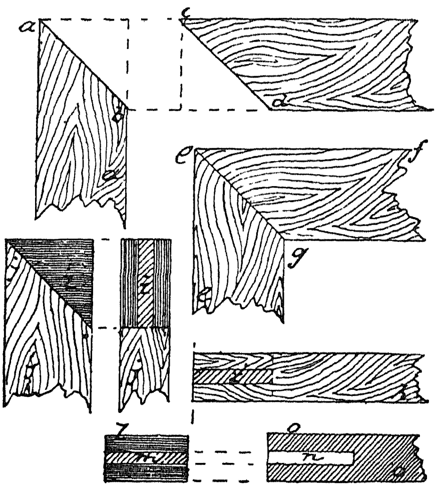

Fig. 53.

tenon joint at the angle. This is shown in detail in the other diagrams in fig. 53. In place of cutting the part, as shown by dotted lines at *a b*, right off across its thickness or edge, a thin part forming the tenon is left in the centre of the thickness, as at *i* in the piece *j j* shown both on side and edge view. On the angular or mitre face of the other piece, as *c d*, a groove in the centre is cut a little less in breadth than the thickness of the tenon *i*, shown in plan of top edge at *n* in piece *o o* corresponding to piece *c d*, which is side view. When the two pieces thus formed are put together they present the appearance as at *h i*, which is a view of top or plan.

Various joints are illustrated in connection with partitions, joists,

and roofs, which form the subject of succeeding paragraphs. Some of these joints employed in the construction of those classes of framed carpentry work have already been illustrated, and to these reference will again be made. We now proceed to illustrate others, the whole comprising almost every kind of joint used in framework. In examining at a future stage of study the illustrations we give of partitions, floors, and roofs, the young carpenter should have no difficulty in seeing at what points the joints now to be illustrated are employed. Reference will, however, be made to the most important points of these.

Special Joints used in the Framing of Partitions.

In fig. 54 we illustrate a method of joining used in partitions. *a a* is part of the sill, *b* the upright post or stud, the joint being a mortise and tenon; *d* is the foot of one angular brace or stud, let in at *e* into a recessed part cut out in the upper face of sill or cill *a a*

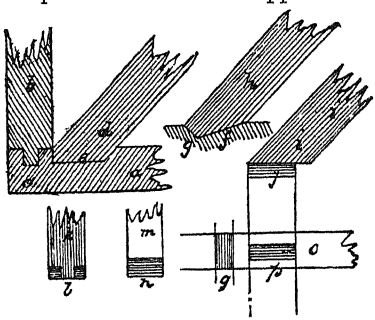

Fig. 54.

This recessed part may be cut out right across the face of sill, and the end of *d* left square. A better class of joint, however, is had by leaving a tenon, as *j*, at the foot of the piece *i i*, corresponding to *d*, which tenon goes into a mortise cut in the face of part cut out of sill *a a*. This mortise is shown at *p* in piece *o*, which is the upper face of sill; *m k l* and *m n* are other views of this joint. The end of brace or strut *d* is sometimes cut angularly, as at *g f* at foot of *h* corresponding to *d*. The filling-in pieces, as at *a b*, fig. 6, Plate I., of a partition are jointed between the face of a strut or brace *a a*, by simply cutting the foot of *b* at the desired angle; the upper end being level or horizontal to correspond with the under side of the horizontal head of the partition, and filling-in pieces, as *b*, being simply jammed and driven tight into the places. But the better forms of joints for foot of filling in pieces are shown at *c d*, *e f g*,

and at *h*, that at *c* being simply an angular piece cut out right across the face of the stud or brace, as *a a*, the foot of piece, as *b*, being cut to correspond. This joint gives security against the foot of piece *b* sliding down the face of strut *a a*, which the simplest form of joint at *b* does not give; but it gives no security against lateral pressure tending to force the foot of *b* out of contact with face of *a a*. Security against pressure in all directions is given either by the form of joint shown at *f*, this being a tenon cut in end of piece *g*

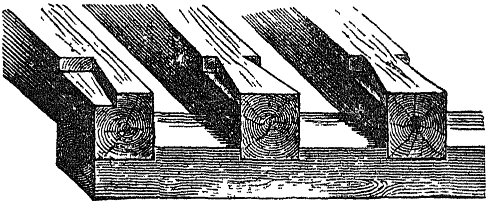

Fig. 55.

and let into a mortise cut in face of brace *e*; or the tenon may be formed as at *h*.

Special Joints used in the Framing of Floors, Joists, and Wall-Plates.

We come now to the joints met with in the framing of floors and roofs of different classes illustrated in a future chapter. Already we have given, in fig. 43, an illustration of the form of joint used in joining the end of a floor joist, *a a*, with the wall-plate *b*. The groove

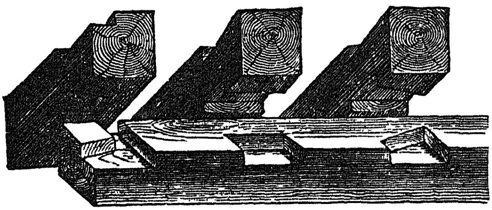

Fig. 56.

c d on face of wall-plate *b b*, with cross-rib or feather, receives the end of the joist, the feather *e* passing into a groove cut in the end of the joist. The lower part of the diagram in fig. 43 illustrates a modification of the dovetail joint for the joining of joists with wall-plates fully described in connection with this figure. Fig. 39 illustrates a method of joining pole-plates *a* with the tie-beam *b* of a roof, forming truss *c d*; in same figure another method, a groove being

cut in the edge of the tie-beam, as at *d*, into which the pole-plate is placed, is shown. In the first method a key, as *e f*, is passed into a groove cut as at *g* in face of tie-beam; a corresponding groove is cut of half the depth of key *f e* in face of pole-plate.

Fig. 38 illustrates the junction of the end of tie-beam with wall-

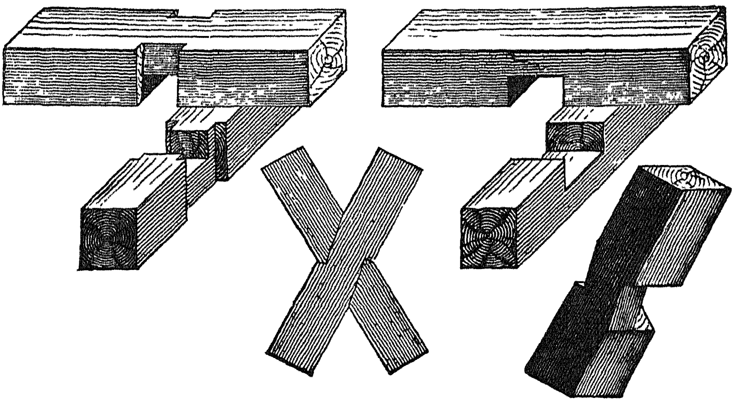

Fig. 57.

plate; fig. 39 giving different views of the parts in fig. 38: *a* is the wall-plate to receive the key *c*, *f* side, *g* end view of the key. In fig. 42 the tie-beam *b* is simply notched into wall-plate *a a*. In fig. 36 a method of notching on the flooring joists, as *a a*, to the sleepers

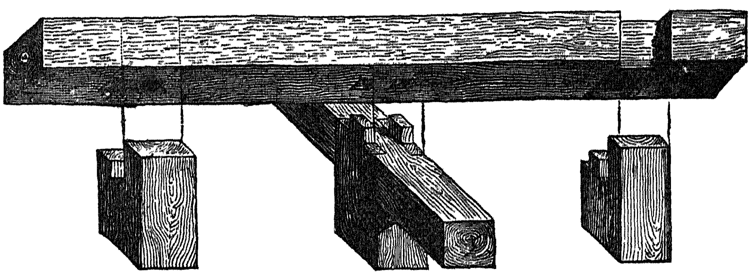

Fig. 58.

as *a*, is illustrated. Those sleepers rest on brick piers, and are generally employed when the width of floor is great, so that a support is given to the joists between the walls. In figs. 55, 56, 57, 58, we give perspective views of several of the joints already described in detail.

Joints used in Roofing.—Common Rafters with Pole-plate.—Queen-Post Roof Details.

In fig. 7, Plate III., we illustrate the junction of a common rafter, *a a*, with a pole-plate *b*, this being secured to the tie-beam *c c* with a key *d*; *c* shows the end of the rafter *a a*, with piece cut out to notch or butt on pole-plate *f g* in cross-section. Fig. 59 illustrates the junction of the rafter, *a*, of a "lean-to" roof (see a future chapter) with the wall-plate *b*, the gutter *c* being secured to ends of the rafters, which are lengthened or extended so as to pass beyond the front wall.

Fig. 60 illustrates the junction at part of a "queen post" roof truss (see a future chapter on Roofs). *a a* is part of the "principal rafter," *b* the purlin supporting or carrying the "common rafter" *c c*.

Joints used in Roofing (*continued*).—**Junctions of Purlins with Rafters.**

The purlin in this is notched or grooved into the rafters, but in

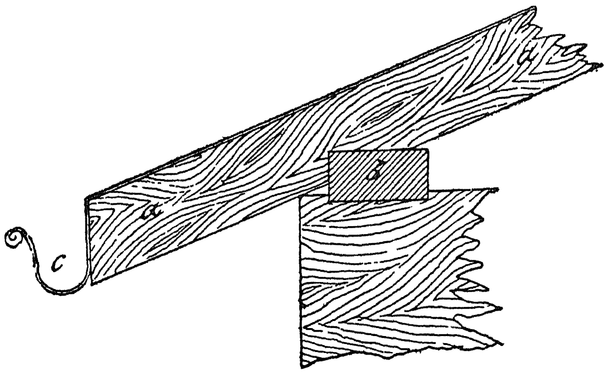

Fig. 59

fig. 61, showing another arrangement, the purlin *a* simply rests on the face of "principal" *b b*, and is supported by a block *a* at its lower end, let into rafter by a tapering notch, as at *a* in side elevation of principal. The block may either be secured by nails to the rafter and the purlin, to prevent lateral movement, or have a key, as *a*, fig. 63, cut in the centre of the notch in face of principal, as at *b*, and in the under side of the block *c*, fig. 61. In fig. 7, Plate I., *b* shows the form of notch into which the end of the strut *d*, fig. 60, is "housed," as the technical phrase is, to indicate when a timber is placed permanently into the part intended to receive it. A simple form of notch is shown at *e*, fig. 60. In fig. 61 *a′ b′ b′ c′* is end view of fig. 60, looking in the direction of the arrow *e*.

Fig. 63 illustrates, in diagram A, methods of connecting feet of rafter *a b* of roof with wall-plates *c d*; *e f* in diagram B illustrates

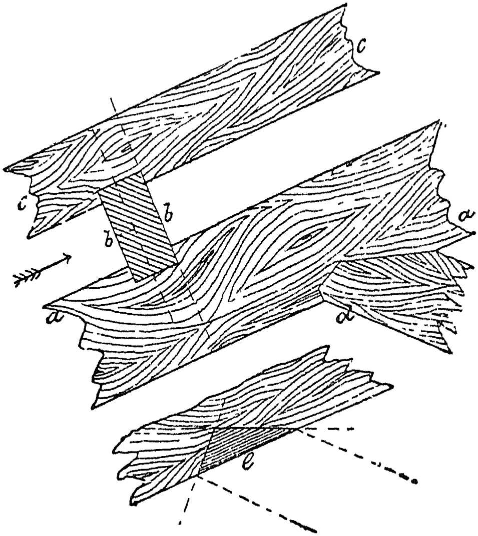

Fig. 60.

the feet of what is called "ashlets," *g h*, with a wall-plate. The

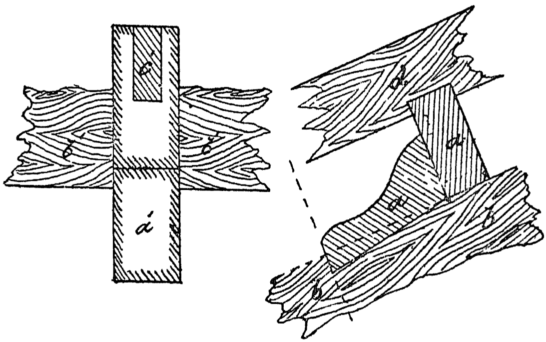

Fig. 61.

ashlet is a timber used in attic roofs to form at the sides a vertical

part of wall surface in place of running the floor right up to the angular space formed by the rafters.

Roofing Joints—Feet of Principal Rafter with Tie-beam.

The junction of the feet of "principal rafter" with the ends of tie-beams is a most important point of carpentry work. The simplest but weakest way is shown at *a b e*, diagram C, fig. 63, the flat face *a b* of foot, bearing on the upper surface of tie-beam *d*, being prevented from sliding away by the strength of the nails. To prevent this dangerous tendency, the foot of the principal is provided with a butting joint, as *e*, let into a notch cut on upper edge of tie-beam; this butting end, *e*, is strongest when it is made at right angles to the line of principal, as the line *f* to the line *g*; an end section is at *h*. Fig. 7 illustrates other forms of joints of this class. In the form

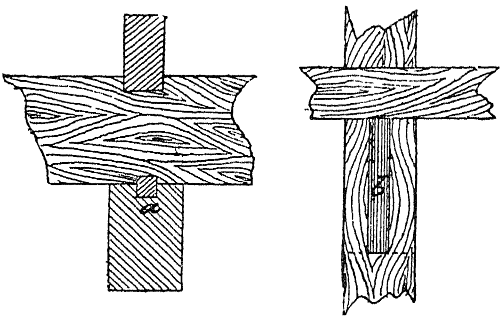

Fig. 62.

in diagram B a longitudinal mortise or groove, *a*, is left in the centre of the notch in tie-beam *b*, a corresponding tenon or rib being cut in the foot of the principal; *e* is section in line *c d*, *f* cross section of tie-beam. Fig. 65 illustrates the junction of collar-beam *a* with rafter *b*, a part, as *c*, being cut out for half the thickness in rafter, and a corresponding part, *a a*, cut in end of rafter of half its thickness, so that the two when joined as at *a b* form a "half lap" joint, as shown in horizontal section *e d* and vertical *f*.

Fig. 2, Plate I., illustrates the junction of parts in a form of roof hereafter illustrated, *a* being the principal rafter, *b* the common rafter, *c* the purlin, *d* the brace or strut housed at foot into face of tie-beam *a e*. Fig. 8, Plate I., illustrates the junction of purlin in a collar or beam roof: *a* collar beam, *b* rafter, *c* purlin.

Roofing Joints.—Junction of King and Queen Posts with Tie-beam.

The junction of king post and queen posts with tie-beam, straining beams, etc., now comes to be illustrated. In fig. 25 (*ante*) we illustrate junction of foot of king post *a* with tie-beam *b*, this being simply mortised into the tie-beam *c*; *d* shows two joints of foot of brace with the king post in front elevation in diagram. In fig. 4, Plate IV., we give side or edge view of drawing in fig. 65. In fig. 65, *a a* is king post, *b b* principal rafters framed into ditto, *c c* common rafter butting either simply on end, secured to side or head, or the ridge pole *d d*; *e e* represents the roofing boards on which the

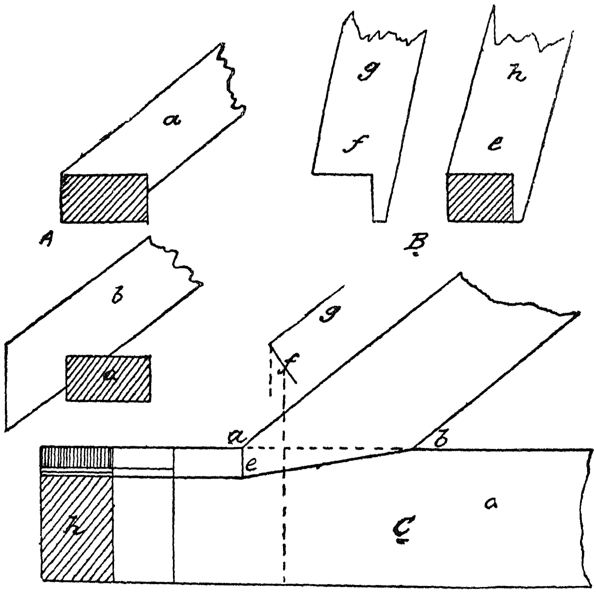

Fig. 63

slates are fixed. Fig. 5, Plate IV., in A shows elevation of another method of tenoning end of principal to head of king post *b b*; in diagram B, *a* shows mortise in head *b b*. Diagram C is plan looking down in direction of arrow in fig. 65; corresponding letters indicate corresponding parts. Fig. 26 shows tenon joint of the assemblage of timber at foot of a queen post *a a*, diagram A; *b b* tie-beam, *c* strut or brace tenoned into foot of queen post, which is secured to tie-beam *b b* by tenon *d* and wedge *e*. In diagram B, *d* is part of "straining sill," *e e* of queen post.

Continuing our remarks on roofing joints, junction of king and queen posts with tie-beam, we give in Fig. 6, Plate IV., the assemblage of timber at head of queen post *a a* in diagram (elevation) A; *b b* end of principal rafter tenoned into queen post, in the side of which, opposite to principal, is the straining beam; *c* common rafter, as at *d*, *e* purlin. In diagram B another method of joining end of common rafter to head of queen post is shown.

In the joints used in framing which in preceding paragraphs we have illustrated and described, the two pieces or members which go to make up the joint as a complete arrangement, each piece has been supposed to be of the proper dimensions—in length, breadth, and thickness. It frequently happens that while the dimensions in

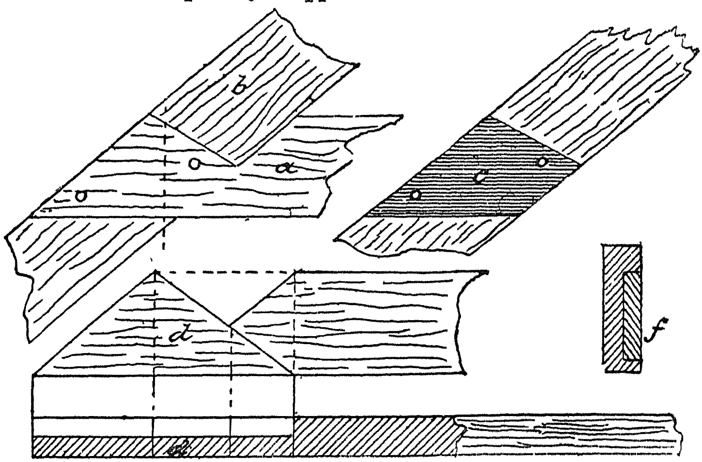

Fig. 64.

section—that is, in depth or thickness and breadth—can be easily enough obtained, the length is deficient; and it is difficult, in many cases impossible, to procure a beam having the requisite cross-section —breadth and depth—with a length in one piece sufficient for the work to be done, or for the office the beam has to fulfil. Hence methods in practical carpentry have to be resorted to to make a long beam out of two or more short ones.

It is to the devices employed in doing this essential work that we now propose to direct the attention of the reader. If he will refer to the various joints we have in preceding paragraphs given, he will see several forms which are obviously devices for lengthening short timbers—that is, for making a piece practically one out of two

separate pieces, either equal or unequal in length. All the joints used in connecting two pieces both of which when put together lie in the same line, either horizontal or vertical, are of this kind. But there is this distinction between those joints we have already given and those we are now about to present to the notice of the reader, namely, that they are usually adopted for pieces of small scantling comparatively, whereas the devices now to be illustrated are employed for pieces of large section, and which are commonly called beams. We have given a wide variety of joints adapted for the junction of pieces having different relations to each other; but those we are now about to give are used only where pieces are to be joined in the direction of their length.

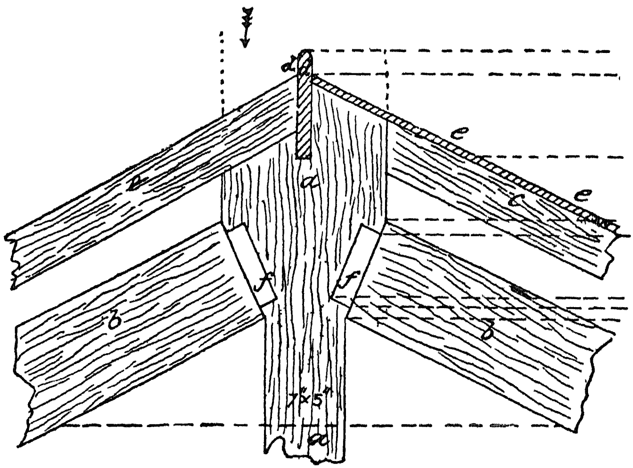

Fig. 65

Beams are lengthened by one of two methods—"fishing" and "scarfing." The simplest method of "fishing" a beam is illustrated in fig. 66; in this the two beams are placed together so that a short part of the length of each rests on the face of the other piece, as at *a a*, *b b*, and when so placed secured together by means of a rope, as at *c c*. It is obvious that if the two pieces are round in section the joint will be anything but a firm or secure one, as each piece has a tendency to ride or roll upon the other. A much more secure joint in this, the simplest and rudest way of lengthening a beam, will be had when the pieces are square in section, as *d d*, *e e*; and the junc-

tion may be made more permanently secure by binding or tying them together by iron straps, as at *f f*.

But, however secure may be the joint effected by either one or other of those two methods of fishing,—and they are often adopted in rough work, as in bricklayers' and builders' scaffolding—they obviously give a very inconvenient form of joint, from the projections they offer,—these quite interrupt the continuity of the piece con-

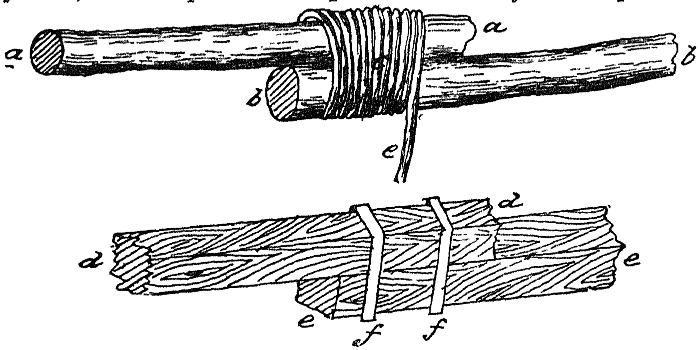

Fig 66.

sidered as a single member, by the "steps" formed in opposite sides, the upper and lower, of the beam. Another method of fishing a beam is therefore usual.

This gives a perfectly flush surface to the united pieces throughout the whole length of the member, considered as a whole. This method is often called "splicing," more especially by seamen, with whom it is a favourite method of gaining one strong piece or spar of timber

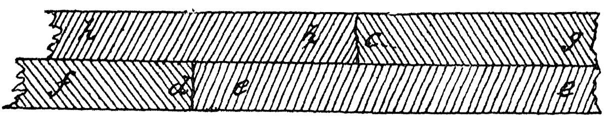

Fig. 67.

out of two short or broken pieces of unequal length. The term "splicing" no doubt originated with them. As to the other term, "fishing," which is applied to the method—although this also appears to have a maritime origin—it is apparently a term which is a corruption of the French word *afficher*, to fix or place and secure one body in contact with the other. Fig. 12 and fig. 67 illustrate the method of fishing timber known as splicing, and which gives a piece as a

whole actually more strength than the original piece, supposing that the new piece is to be formed out of the two pieces of a broken spar, for example. If *a* and *b*, fig. 12, represent the two halves or pieces into which the spar has been broken, each half or part is cut up longitudinally in the direction of the dotted line—thus giving four pieces, two short, out of the piece *a*, and two of them long, as got out of the piece *b*. The pieces are then placed as in the diagram in

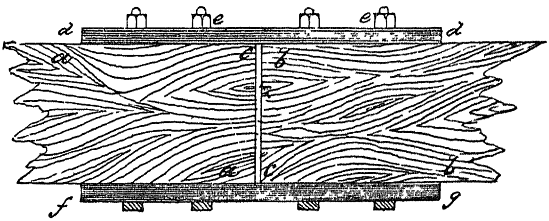

Fig. 68.

fig. 67; so as to "break joint," the joint *c* of the junction of the short piece *c g*, and the long one, *h h*, butting against the solid part of the lower long piece *e e*. In like manner the joint of the short piece *d b*, and long *e e*, butts against the solid part of the upper longer piece *h h*. Such is the effect of this simple, yet thoroughly scientific —in a constructive sense of the term—method of jointing the piece of a broken part, that the spliced or half arrangement, as in the

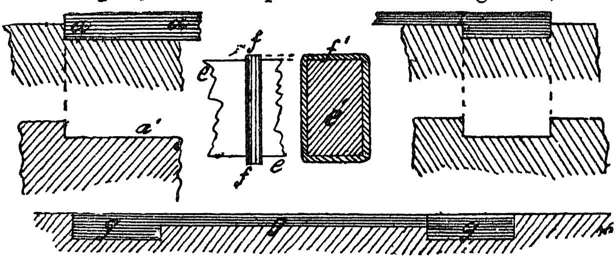

Fig. 69.

lower design of fig. 66, is actually stronger than the original unbroken piece. In ship carpentry the pieces thus "rigged out" are held together by strong tarred rope; but in carpentry, as applied to general work, bolts and nuts, or strips of hoop iron bond or rings of wrought iron, are slipped in while hot, and shrunk by becoming cool.

The methods used for joining timber by that known as "scarfing" —are pretty numerous: fig. 9, illustrates the "scarfing" of two

pieces *a* and *b*, the end of each piece being cut longitudinally in the direction of the centre of the two pieces; so that when laid together they are "flush" with the general surface. The joint is called generally a "half-lap" one. The two pieces are secured together by iron bolts and nuts, as at *c*, *c*, *c*; *d d*, *c′ c′ c′* in the lower diagram showing the bolt holes in the lower piece *b′b′*, corresponding ones being bored in the upper piece *a′ a′*. The term "fishing joint" is also applied to the method of joining two timbers as illustrated in fig. 68 —the ends being simply squeezed up, and there being no lapping or laying of one piece or part of a piece upon another, which is the distinguishing feature of all "scarf" joints. The pieces butt at their ends with even joint, as *c*, and the two are held together by "fishing plates"—one, as *d d*, at the upper side, the other, as *f g*, in the lower side of the two beams. The "fishing plates" are sometimes partly

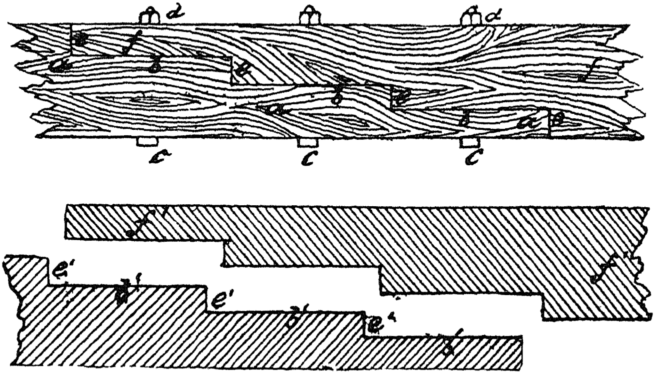

Fig. 70

sunk into the beams, as shown at *a* in fig. 69—or formed at end, as at *g*, and that to the right are part sections. In place of bolts and nuts, as at *c c*, fig. 70, hoops of wrought iron as in cross section at *e′ f′*, fig. 69, and part side elevation at *e e*, *f f*, shrunk on shows the complete fishing plate. Iron fishing plates are the best, and being thin, are often sunk into the faces of the two beams, so that the surfaces are flat, the only projecting parts being the bolt heads and the nuts.

Fig. 3, Plate III., illustrates the system of joining timber together by what is called "scarfing," the joint *a b*, fig. 10, being at an angle or oblique to the faces of beam to be joined. The joint is technically called a "table," and some forms of scarf joints (they are pretty numerous) have several tables: see fig. 3, Plate III. The

two beams are secured at the joint by bolts and nuts, or by "shrunk-on" hoops of iron. To make the joint still more secure, in some modes of scarfing, keys of hard wood are driven into apertures cut in the tables of the scarf—one-half being in one, the other in second half of beam. This is illustrated in *c* and *d*, either as at *d* in the centre or as at *c* in the corner of the scarf, fig. 4, Plate III. Fig. 9 illustrates a mode of scarfing when the tables are parallel to the faces of beams.

In fig. 3, Plate III., *a a* is the lower, *b b* the upper beam; the ends of each being cut so as to give an irregular or oblique "table," as *d d*, finished off at the ends obliquely as shown. The two are secured together by bolts and nuts. The lower diagram, B, shows the two pieces separated and in section; the letters of reference accented being the same as in the upper diagram. In this the single table of the method illustrated in fig. 10, is represented by a series of tables as *d d*, *e e*, these alternately projecting as *d′d′* in the section in diagram B, and recessed as at *e e′*, interlock, so to say, with one another, and thus prevent movement under pressure. The two are

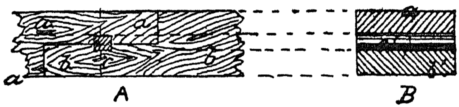

Fig. 71.

secured together by bolts and nuts, or by straps. The diagrams in fig. 4, Plate II., show a method sometimes adopted in this form of scarf-joint, a key, as *c*, being placed at the corner of the projecting point of the table *b* on beam *a a*. Keys are sometimes put in the flat part of tables of scarf-joints, as at *d* in beam *e e*, in diagram C, same figure. This method of keying may also be applied to the scarf-joint in fig 70, as at the centre of the tables *b*, *b′*, or at the ends, as *e*, *e′*. In this figure the upper diagram is elevation, showing method of securing the two beams together by bolts and nuts *c c*, *d d*; the lower diagram shows the two separate and in section.

Fig. 11 (text), upper diagram, illustrates a form of scarf-joint in which a horizontal table, as *a a*, is used with an oblique one at *b b*. A key, *c*, being put in at their point of junction, the two are secured together by bolts and nuts, *d d*, *e e*. The lower diagram is section with beams separated.

Concluding Remarks on Scarfing or Lengthening of Beams.

In the preceding paragraphs we gave descriptions and illustrations of different methods of lengthening beams,—that is, of making one

long beam out of two short ones,—those being known as fishing and scarfing, the latter being the more generally employed. We now proceed to describe the methods employed for adding to the strength of beams, so as to enable them to carry heavier weights or sustain greater pressures than those the strength due to their natural or given dimensions enables them to resist or bear. But before giving our illustrations of these methods, it will be well to add to what we

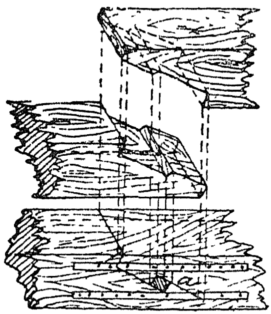

Fig. 72.

have already said on the subject of lengthening beams by fishing or scarfing, the following considerations. By giving the "tables" or bearing surfaces of the joints, and adding the bolts and nuts or straps by which the pieces are bound, the two pieces of wood joined in this manner are as solid as one piece of the same size made out of a single piece, provided always that the strain is given only in the direction of the length of the piece, because the joint is arranged in such a

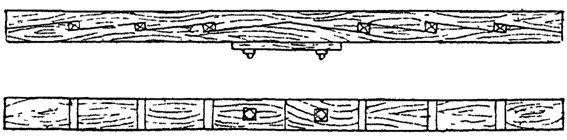

Fig. 73.

way as to resist a force of tension or pulling rather than a strain of cross or tranverse pressure. The surfaces of the tables are generally cut obliquely, and the cuts are kept together by a strong square oaken peg, which should press the faces firmly together. The pieces of the joint are united or held together by means of iron hoops, or, as we have already shown, by bolts and nuts. Generally these hoops or bands are made to go round and embrace the beams completely;

sometimes in place of encircling hoops the bands are confined to plates or strips, which are placed on each side of the beam, as shown in fig. 72, *a* the iron plate or band, bolted to the beam. This is sometimes let into the beam or, as more generally adopted, simply laid on the surface. There may be two, or even three of these plates, in the depth or side of the beam; and in addition top or bottom plates may be used, as illustrated in fig. 73. In place of plain-surfaced "tables," or skewed or oblique surfaces being used in scarfing, as in fig 10, the faces of the tables are cut up into tenons and mortises as in fig. 3, Plate III., or fig. 11 (text), but this is only done in special cases. The first quality of a joint is great accuracy of fitting of the surface, and it is very difficult to cut quite exactly pieces so complicated. Generally the form of scarf-joint used is that with two inclined faces, as in fig. 10, taking care always to add hoops or bands of iron as shown, or bolts and nuts as in fig. 9.

When the pieces are intended to be placed vertically, they are joined by tenons and mortises, as shown in fig. 32.

We have now shown in succession the principal joints used in carpentry. Custom will teach us how to modify their proportions

Fig. 74.

according to the work that is to be executed, and with due regard to the quality of the wood employed.

In executing joints we should never deviate from the rule which enjoins that the projections formed by the grooves and sections at the end of one piece that is to be joined into another shall be according to the grain of the wood and without interruption, in order that no splinter may break away. Dovetailed joints, and the form of scarf as in fig. 4, Plate III., are exceptions to this rule; but we may rest assured that their length and the inclination of their sections are such that there can be no reason to fear the breaking off of any of their parts. A second rule which ought to be adhered to is that the divisions and grooves cut out to receive the joints must not have any part of the same kind weaker than the others, since they must all resist pressure equally.

The Strengthening of Beams.

We now turn our attention to the methods of strengthening beams, the first we take up coming under the term or designation of "built beams."

When we wish to increase the strength of a beam which, besides its own weight, has to support a load too heavy for its natural section or dimensions, we have recourse to different methods which we are now going to point out.

We might at first rest satisfied by placing a second beam by the side of a beam which is too weak, and thus sharing the weight between the two; but, in this case, the resistance of the two beams would be simply equal to the amount of the resistance of each. If, on the contrary, the pieces are united by well arranged and secured joints, or if they are bound together by bolts or hoops, in such a

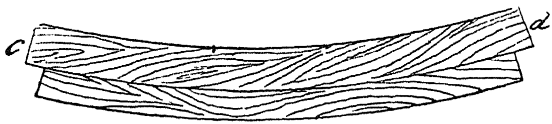

Fig. 75.

way that from their union may be obtained a solid body, all the parts of which shall be conjointly liable, so as to remain in juxtaposition at the time of bending without the possibility of slipping one against the other, we shall obtain a great increase of strength.

To obtain the result which we have just pointed out, we join pieces of wood in the form as shown in fig. 76; but we must remark that the arrangement of the grooves is very important relatively to the effect which they are to produce. If we have two pieces of wood superposed one upon another, as the beam *a a* upon *b b* (fig. 74), not fastened together, and surmounted by a weight placed in the middle,

Fig. 76.

this load will make them bend, as in *c d* (fig. 75); thus the points of the upper piece will have slipped over the under piece. It is this slipping which must be prevented by means of a joint, so as to give points of resistance, and we obtain this by making grooves like those represented from *f* to *g* (fig. 76), and by securing the two pieces together by means of bolts. By this arrangement the bolts are subjected to very little strain. It is easy to understand that if the grooves were made the contrary way, as in fig. 77, they would have no effect; we must, therefore, before fixing their position, take into account the amount of strain which they will have to resist.

Practically it would be very difficult to make the grooves, such as we have just pointed out, with such precision that there shall be no space left between the faces of the grooves. Yet it is evident that if the grooves are not firmly fastened together we shall not obtain the desired effect. To obviate this difficulty we have recourse to keys or square trenails made of hard wood, driven firmly between

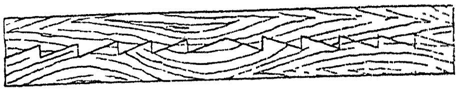

Fig 77.

the grooves, as we have already seen illustrated in fig. 4, Plate III., and as shown in fig. 73.

As the resistance of wood is much greater according to its length, we have recourse to another kind of iron brace, which consists in strengthening the beam by means of two pieces, as *a* and *b* (fig. 78). These two pieces have the tendency to swerve or bend from the

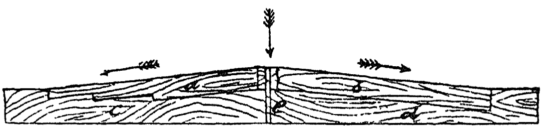

Fig. 78.

straight line in consequence of the weight which they bear, and consequently divert or change the pressure in the direction of the length of the beam *c d*, as shown by the arrows. The illustration shows two ways of joining the pieces *a*, *b*, to the beam *c* by means of one or more scarfs, as at the piece *a*. The two pieces butt at the upper ends, and are united by an iron hoop or band *e*, as shown.

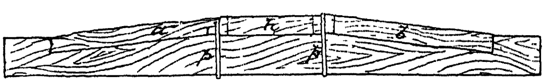

Fig 79.

Fig. 79 is also composed of two pieces, *a* and *b*; but these are separated by a horizontal piece, *h*, to avoid giving too great a height in the middle of the beam. *p*, *p*, are bands or hoops of iron binding the whole.

In fig. 80 the upper part of the beam is cut in a curve, so as to make the ends only two-thirds of the height of the middle; then, upon this first piece is placed a second, which is bent by means of

bands of iron, *l l*, in such a way as to make all the parts of the beam join exactly. This arrangement very nearly doubles the strength of the piece.

In another method of building beams the two pieces have grooves cut across their faces into which keys are driven, and the whole secured by iron hoops. In fig. 81 we illustrate a method of forming an exceedingly strong beam out of thin planks or deals. It is gener-

Fig. 80.

ally employed in the formation of curved rafters for roofs of large span; the planks are placed in contact with each other, as shown at *a b c d e f*, in fig. 81, and care must be taken that they "break joint"—that is, that the joint of any two contiguous pieces, as the joint *m*, shall butt against or be placed at the solid parts, as *n* and *p*, of the pieces *o o* and *q q*. This may be taken as a section on a larger scale of assemblage in figure above on the line *g h*. The

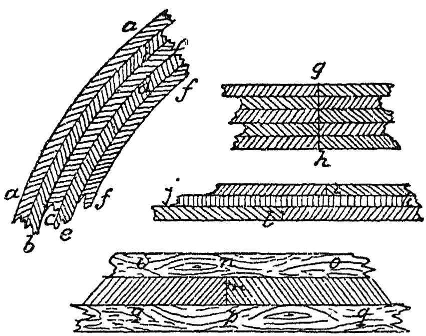

Fig. 81.

diagram then further illustrates the system of "breaking joint"; the joints *k* and *l* butting against the solid parts of the central piece *j*. When we come to the consideration of roof framing we shall further illustrate the methods employed of forming built beams for the curved rafters of roofs of large span—proceeding now to the consideration of the second method of strengthening beams by the employment of the principle of "trussing." Some of the methods

of scarfing of beams already illustrated may be taken as examples of built beams.

Framing.—Beams in Framework.

When a beam of any length, as *a a*, fig. 82, is placed to cross or span a void space, as between two walls, *b b*, a weight acting at *c*, or distributed along its whole surface, or even the weight of the beam itself, gives the beam a tendency to fall down in the centre, as shown at *f g* in the beam *e f g*. If the weight acts entirely at the centre, as in the direction of the arrow *d*, the tendency of the beam to bend is at its greatest. Hence, in all framing the object of the designer is to distribute the weight over the whole beam as uniformly as possible. Thus weighted, so to say, a beam can support or carry

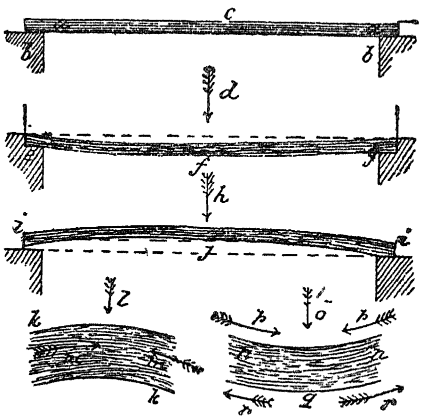

Fig. 82.

a much heavier weight than when loaded at the centre. How much and in what way pressures act upon beams, and how they are calculated, will be fully discussed when we come to consider the principles of framing. The bending of a beam is technically called its "deflection." As we have said, all beams have a tendency to deflect; and of course the more carefully calculated and constructed, the less will be the amount of deflection. To provide for the deflection, beams when of wrought iron or steel are made purposely with a bend in the opposite direction, as in the diagram *i i*; so that when placed *in situ*, and the pressure brought to bear on its upper surface, as in the direction of the arrow *h*, the deflection brings the beam down to its proper level line, as *i i*. The amount of opposite flexure or curvature given to a beam thus is called its "camber."

The two principal strains to which materials are exposed in all framework are tensile and transverse or cross strains or pressures. A tensile strain has a tendency in a timber beam to tear its fibres apart in the direction of the length of the beam; a transverse or cross strain or pressure has a tendency to break it across in the direction of its breadth. A tensile strain may be popularly described as a pulling, a cross or transverse as a pushing strain. The strain known as that of "compression" is that which tends to squeeze or force the fibres together, and may so disturb them as to cause a beam, as a vertical column of timber, to bulge out at one part, and thus be broken. A beam placed under such circumstances, as *a a b b c*, fig. 82, with a "distributed" load at upper side, or a single pressure acting at centre *c*, is placed under two distinct strains under the deflection. Thus let *h* in fig. 82 represent the central part of the beam *a a*, deflected by a heavy weight or pressure at *c* in upper diagram; this deflection, shown in an exaggerated manner, gives a concavity to the upper side and a convexity to the lower. Under those circumstances the fibres on the top side are placed under compression, tending to force or (to use the popular term) squeeze them together in the direction of the arrows *p*, *p*, towards the centre. On the under or convex side, *q*, of the beam, the fibres are, on the contrary, pulled or extended outwards, as in the direction of the arrows *r*, *r*, from the centre *q*. The fibres are here thus put under a tensile strain. The combination of the two strains—that of compression (known also as "compressile" or "crushing") at the top surface, *p p*, and of tension ("tensile" strain) at bottom, *r r*—if carried far enough, will break the beam. The youthful reader is recommended to take a thin strip of wood and bend it round: he will, by carefully examining the effect of the strain or pressure thus put on it, have a fair idea of how the two strains act. The effects we have just described are precisely of the opposite character in a beam deflected or bent in the opposite direction, as at *k k l* in fig. 94. The fibres on lower side are those which are under compression; those of the upper under tension. Beams of timber are better calculated to resist strains of compression than of tension; and the "trussing" of beams, as this work is called, has for its principal object the providing against the tensile strain to which it may be subjected.

Framing.—Strengthening of Beams.

If the reader will remember what we have said as to the tendency of all loaded beams to deflect or bend downwards in their centre—a result also of beams of considerable length, the weight of the materials alone acting at a distance from the supports—and what are the

results of these strains upon the fibres of the wood, he will see how one method adopted in some cases of strengthening a beam by enabling it to resist the strains brought into existence in a deflected beam, or calculated to increase the deflection, meets the necessities of the case. The method consists in cutting out grooves in the upper side of the beam, and filling them in with wedges or keys of a very hard wood, as at *g g*, fig. 1, Plate VIII. The effect of this arrangement is illustrated in the upper diagram in the figure. If a triangular-shaped groove, *a*, is cut out across the face of a beam, *b b*, before it is placed in position, when so placed the pressure put upon it causes deflection; and from what has been said in connection with diagram *p p q*, in fig. 82, the groove *a*, in fig. 1, Plate VIII., will be closed either partially or wholly according to the degree of pressure, this acting in the direction of the arrows *c*, *c*. But by driving in a wedge of hard wood, as at *d*, the pressures still acting in the direction of the arrows *e*, *f*, will be resisted; and the harder the wood of *d*, and the more the pressure of *e f* resisted, the less tendency will there be in the beam to deflect, as at *f* or *q* in fig. 82; and thus the tendency of the pressure to put the fibres of the under side, as *q*, under the strain of tension, will be prevented at the point where their action is greatest—and which strain of tension we have seen that timber is least calculated to resist

Of all materials used in construction, wrought iron is the best calculated to resist tension or tensile strains, cast iron to resist compressive or crushing forces. These two materials, therefore, we find, have been largely used in the trussing of beams. Thus the wedge *d*, or the keys or filling-in pieces *g g*, of hard wood in fig. 1, Plate VIII., are, as we have seen, put under a strain of compression or crushing; but by substituting for wood cast iron, we obtain a material much better fitted to resist compression than oak or other hard wood employed in construction. If cast iron be used, it is the best way to employ it as a plate let into a recess cut in the upper side of the beam near its centre. This is partly seen at *h* in the beam *i i*, fig. 1, Plate VIII. Fig. 6, Plate VIII., illustrates methods of securing the cast-iron plate used as at *h* in fig. 1, Plate VIII. This may be done either by bolts and nuts, as at *q q*, *r s*, shown in detail in section at *f g h i*; or, to obviate such weakening of the beam as bolt-holes might cause, the plate may be secured to the beam by bands or hoops of wrought iron, as *a b c d*—in side elevation at *e e*—and "shrunk on" while hot; or the hoop may be made in split hoop, as at *k k*, brought together when passed over the beam, and secured by the small binding bolt and nut *m l*. To secure the full effect of the cast-iron plate, it should be let into the upper side

of beam, as at *q q*—not merely laid on the surface, as at *n n*—as the strain in this case is brought chiefly on the bolts or hoops; whereas by the method shown at *q q r s* the strain is brought chiefly upon the beam in the direction in which it is strongest, and partly only upon the bolts or hoops.

Some years ago the Society of Arts awarded a prize to a Mr. Smart for an improved method of strengthening a beam on the principle of compression, as illustrated at *d* in fig. 1, Plate VIII. In the beam *a a*, fig. 3, Plate VIII., a narrow part is cut out, or a thick saw draught is made, as at *b b*, and near the end of the beam a triangular or wedge-shaped part, as *c*, is cut out, to a certain depth across the upper face or edge of the beam. This is done at both ends; and the part *b* extends along nearly the whole length, stopping short at some distance from the parts cut out, as at *c*. The beam is thus partly divided into two in the direction of its width or thickness. In the centre of the upper part *d* a piece is cut out. This is of width sufficient to admit a hard-wood wedge of the form as shown in section at *a*, in fig. 2, Plate VIII., or it may be made of cast iron. Before this is inserted, the upper parts, as *d*, fig. 3, same Plate, are lifted up. This can be done without breaking them off from the lower part, as *a a*, inasmuch as the open grooves at *c* close from the compression of the fibres in the direction of the arrow *f*. When fully lifted the parts cut out at *c* close up, with the block *a*, fig. 2, Plate VIII., inserted. This makes the beam assume the form shown in the figure, the upper part, *b b*, being separated from lower, *c c*, by the triangular opening *d d*. We look upon this principle of strengthening beams as capable of being adopted with useful effect in a wide variety of work. A modification of the method illustrated in fig. 1, Plate VIII., at *d*, is shown in fig. 4, same Plate. In this a saw draught is cut out across the upper face of the beam, and it is then bent upwards till the saw draught opens, assuming the form of a triangular opening. Into this the block of hard wood or of cast iron, *a*, is inserted, when the pressure keeps this tight. By this arrangement a small beam may be made capable of bearing a much greater weight than it would do in its original form. So also is this the case when the beam is treated as in fig. 5, Plate VIII. In this the saw draught or piece cut out, as at *b b* in fig. 2, Plate VIII., extends to very nearly the ends of the beam, and is there strengthened by iron hoops, as at *a*. The two parts, as *b b*, *a a*, are then opened and extended, and two wedge-shaped blocks, as at *d e*, but in reversed position, are inserted. This is a modification of the method illustrated in fig. 2, Plate VIII.

We have just said that wrought iron is admirably fitted to resist

tensile or pulling strains, and that advantage is taken of it in trussing beams to strengthen them. The simplest way is to secure a plate of wrought iron, as *j*, fig. 1, Plate VIII., to the under side of the beam *k*; but, although this is a position well fitted to resist those tensile strains at the under side of the beam to which all beams are more or less subjected—even a beam supporting, as we have seen, only its own weight—yet this method has obviously its inconveniences, and another is preferred in practice. This is illustrated in fig. 7, Plate VIII., and which represents in diagram what is called a "flitched" or "sandwich" beam. The derivation of these names, especially the latter, is obvious enough, as they indicate that a plate of wrought iron is placed between two wood or timber beams, and the whole bolted together. The top diagram illustrates the whole beam, *a b*, as thus flitched in elevation; the centre diagram one of the beams—the off one, *c d*—with the wrought-iron plate shown in lines. The lower diagram is a plan of top as looking down upon the whole beam, *e f* being the off beam, *g h* the near one, with the plate of wrought iron between them. In fig. 1, Plate IX., the upper diagrams show in detail the method of flitching a beam, *i* and *j* being the two beams at the end, with the "sandwich" or "flitch" of wrought-iron plate, *k*, secured by the bolt and nut at *l m* passing through the whole. Bolts and nuts are in this case passed through the central part of the beams and flitch, as at *n a p q*, not merely at the ends, as in *a* and *b*, fig. 7, Plate VIII. In place of the iron plate lying or pressing on the surfaces of the two beams, as at *s t*, the plate may be let into one of the beams, as at *o* and *r*; or a part equal to half the thickness of the plate may be cut out of each beam face, as at *y* in the lower diagram, in which *w w x* are the two beams in part plan. In either of these arrangements the two faces of the beams can be brought up close to each other; and another advantage will be obtained—that the ends of the plates would butt up against solid timber, and thus act in some measure as a compressive strain.

In trussing beams on the methods now to be illustrated, iron in its two forms of "cast" and "wrought" is used in combination with the timber beams, the cast iron to resist "compressile," the wrought iron to resist "tensile" strains. How they are used to perform these offices we now proceed to show; taking first the trussed beams in which cast iron is used.

Fig. 8, Plate VIII., gives in diagram one arrangement for trussing. The upper diagram represents the method in which the two beams to be placed together—one of which is shown at *a b*, *c d*,—are trussed by cast-iron bars, one of which, *e*, is vertical in the centre of the length of the beam, and two, *f* and *g*, inclined at an angle to

this; the inner and upper ends butting against the upper end of vertical bar *e*, the other and outer or lower ends butting against bolts passed through the beam. These bars are placed between the two beams, and take the place of the wrought-iron plate used in "flitching" or "sandwiching" a beam as illustrated in fig. 7, Plate VIII., and in fig. 1, Plate IX. In the middle diagram in fig. 8, Plate VIII., the arrangement is shown of another method of trussing beams with cast-iron bars. In this the off beam, *h h h*, is shown in side elevation, two inclined bars of cast iron, *j k*, butt against bolts in pairs at their feet or lower and outer extremities, and at their heads or upper ends against the ends of a horizontal bar, *i i*, also of cast iron. In both cases two thin beams or thick planks are used, in order by trussing to make one strong beam; and placed in juxtaposition, as in the method of "flitching" illustrated in fig. 7, Plate VIII., and as at *l l*, *m m*, fig. 8, same Plate, have the assemblage of cast-iron bars placed between them, as shown, *n n* being top edge of the bar *i i* in central diagram, *o o* the top edges of bars *k*, *k*, in same figure. In this case the bars are held in position, and they and the two beams thoroughly secured, by screwed bolts passing through the beams at convenient positions at their ends and centres, these bolts being brought hard up by the nuts with which they are provided.

The method of trussing just described, as well as that of flitching in fig. 7, Plate VIII., has this great advantage in the case of a thick beam,—that it may be sawn longitudinally into two, and thinner beams, and the sides which originally formed the central part of the beam, turned outwards in the trussed beam. This exposes what was the centre or heart of the original beam, and allowing it to be exposed to the air it gets thoroughly seasoned, and the decay prevented which often sets in in the heart of thick beams which are difficult to season throughout the bulk. In fig. 9, Plate VIII., we illustrate part of the centre and part of the end of a beam trussed with iron bars, either cast or wrought, although cast iron is better constituted to resist compression than wrought iron. In this the central bar, as *e* in fig. 8, Plate VIII., is dispensed with, and the bars, as *f g*, simply butt against each other at their upper ends, as at *e e*, the ends being cut off in a vertical line. The lower ends, as *b c d*, in place of butting against a bolt passing through the beam *a*—this bolt forming one of those which secure the two beams together—is let into the face of the beam at *y* in fig. 1, Plate IX., so that the thickness of the part cut out gives a butting place for the end of *a b c d*. The bar *b c d f e* is of course let into the beam along its whole length, and so that it is either flush with the surface of the

beam or sinks so deep that its surface may be a little below the surface of the beam into which it is sunk.

In the case of large beams which are trussed, a more complete method of adjusting the iron trussing bars is adopted. The details of one or two methods are shown in figs. 2 and 3, Plate IX.; the general arrangement being as in the upper diagram *a b c d* in fig. 8, Plate VIII. In the method illustrated in fig. 2, Plate IX., the upper ends of the inclined bars, as *h*, *i*, corresponding to *f g* in upper diagram in fig. 8, Plate VIII., butt against a cast-iron head *e e* at their ends, *f*, *g*. This head *e e* is made thick enough to admit of a bolt-hole to be formed in it, through which is passed a bolt *d d*, which passes down to the under side of the beam, and is provided with the usual form of projecting head which presses against the bottom edges of the two beams, where the bolt is screwed hard up by the nut *c c*. To prevent the nut from sinking into the upper edges of the beam, as *a a*, and to give it a good bearing surface, it is in good practice usual to give a pressing plate of wrought iron, as shown at *b b*, through which the bolt *d d* passes, and against which the nut is jammed or screwed up. This pressing plate *b b* is shown as let into the top edges of the beam so as to be flush with their surfaces. The plan of arrangement in upper diagram in fig. 2, Plate IX., is shown in the lower diagram; in which *a′ a′* is one of the beams, *k k* the other placed in juxtaposition, *b′ b′* the pressing plate corresponding to *b b*, resting on top edges of the beams or let into their surfaces, against which the nut *c′ c′* is jammed or screwed up, *d′* showing end of bolt. In some cases the butting head is not placed between the beams and hidden between them when placed in the position as at *e e g f* in fig. 2, Plate IX., but is in place of being made of cast, formed of wrought iron, as at *e e*, fig. 3, same Plate. The lower end of this is forged so as to narrow at the point *p*, and is from that point continued downwards to form a bolt *i*, which is provided with the usual head, which is large enough to take a good hold or grip of the under edges of the beams. The head *e e* is itself of course flat, so as to give flat edges, as shown at *e′* in edge or side elevation to the right of *e e*, and the bolt *i* or "tail" may be flat also, or it may be rounded, as bolts usually are. The upper part of the head *e e* is extended upwards, as at *h*, and this part is of course rounded, as it has to form the screw bolt by which the head is jammed down or held in position by a nut, as at *c c* in fig. 2, Plate IX. The head *e e*, fig. 3, Plate IX., may be firmly secured to and held in position between the two beams—each half in a trussed beam being generally termed a "flitch"—by having a bolt-hole as shown in the centre near *g*; through this a bolt is passed, and passes

also through both beams, and is screwed up in the usual way. The lower ends of the bars—technically termed "struts" or "braces," generally "struts"—correspond to the bars *f*, *g*, in the upper diagram in fig. 2, Plate IX., and are disposed as shown in fig. 3, same Plate. They press against butting pieces, *j*, *k*, the upper parts being extended upwards in the form of a flat bar or bolt provided with the usual "head" made broad enough to take a good grip of the upper edges of the two flitches or beams. The butting pieces, as *j*, *k*, are in the other or lower direction extended downwards in the form of a round bolt, *m m*, which is screwed to receive a nut which is jammed or screwed up against pressing plates, as *b*, *b*, fig. 2, Plate IX., resting or let into the surfaces of the lower edges of flitches or beams. The arrangement here described may, however, be reversed, the upper part of butting piece *j k* being extended at *j* so as to be finished at end as a screwed bolt, the nut and pressing plates being at the upper edges of the beams, while the lower parts, as *m m*, are kept flat and provided with heads, as usual. In some cases the heads or upper butting pieces, as *e e* in fig. 2, Plate IX., in place of being concealed between the beams or flitches *a a*, being below the upper edges or surfaces, are wholly above and rest upon them. In this arrangement, shown in diagram in fig. 3, Plate IX., at *a a*, *b b*, *c d*, in which *a b* is the head butting-piece, *d* the bar corresponding to *h g* (fig. 2), and *c* the bolt-hole, part of the ends of bars being seen above the beams or flitches. The lower butting-pieces, as *j k*, are always concealed within the beams. These may be let or sunk into the beams, as at *c* in fig. 9, Plate VIII., in order to have a butting or resisting point; but this is provided usually by bolts, as at *o* (fig. 3, Plate IX.), against which they press, those bolts passing of course through both beams, and being jammed or screwed up with screw-bolt and nut. Or the lower butting-piece, *j k*, may be itself bolted to the two beams, the bolt passing through a bolt-hole as at *n*, thus affording the necessary resisting point.

Those of our readers acquainted with "roof" trusses (see succeeding paragraphs on Roofs) will perceive that the two methods of trussing beams illustrated in the diagrams in fig. 8, Plate VIII., are arranged on the principle of the "king post" (*a b c d e f f g*) and "queen post" (*h h i i j k*) principles of trussing. The same methods are adopted in trussing beams with wrought iron; but as this method is best suited to resist "tensile" or pulling strains, the ordinary arrangement of the "king post" and "queen post" trusses are reversed. Thus, in fig. 6, Plate IX., the upper diagram is the "king post" truss, but with the angles of the parts *c d* in the opposite direction to *f g*, corresponding parts in fig. 8, Plate VIII.

And in the lower diagram, *h h* in fig. 6, Plate IX., the "queen post" principle of trussing is shown, but with the parts *h i*, corresponding to *j k* in fig. 8, Plate VIII., reversed. And this, as just stated, is done in order to meet the different conditions in which the material of the trusses is placed. Thus the parts *f g*, *j k*, in fig. 8, Plate VIII., are struts or braces calculated to and so placed as to resist compressile strains or a crushing force; the parts *c d* and *h i*, fig. 6, Plate IX., to resist tensile strains, or a pulling force.

In fig. 5, Plate IX., we give to larger scale the elevation of central part, and in fig. 10, Plate VIII., the plan of under or lower side of flitches or thin beams trussed on the arrangement shown in upper part of diagram in fig. 6, Plate IX. In fig. 5, same Plate, *a b* is one of the flitches, *c d* the wrought-iron tension rod, this passes round the part *e*, the lower edge of which is rounded to admit of the bent part of *c d* pressing equally against it; the part *e* forms the lower termination of the bolt *f*, which is screwed to and jammed up by the nut *h* and pressing plate *g* against the upper edges of the beams or

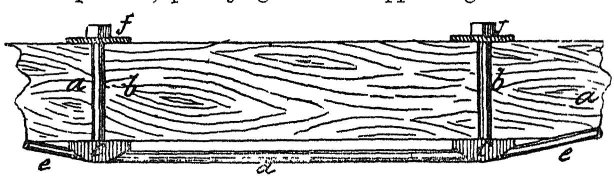

Fig. 83.

flitches. The part *e* is wide or broad enough to have a good pressing surface against the lower edges of the beam, as shown in the plan of fig. 5, Plate IX., in fig. 10, Plate VIII. Fuller details of the arrangement at central part of the truss, and of the method of securing the upper or outer ends of the tension rods *c d*, will be found illustrated in fig. 4, Plate IX.

In fig 83 we give in larger scale the central part of the queen-post arrangement of trussed beam in *i i j*, fig. 6, Plate IX. In this there are two bolts and heads, as *b b c*, placed at same distance apart, between which the tension rod is horizontal, as at *d*, and on passing round the heads *c c* are screwed up at an angle to the upper curves of ends of beam, as shown in fig. 6, Plate IX., at *h i*, and secured in the manner illustrated in fig. 4, same Plate. Fig. 84 (in text) is plan of under side of the truss in fig. 6, Plate IX.; fig. 85 (in text) being plan of top side, showing the pressing plates *f f* for tightening up the truss. And it should be noted here by the reader that this tightening or screwing up of all trussed beams, in which iron is combined with timber, is done to such an extent that the truss as a

whole has an upward bend or curvature, so that it is reversed as at *i j i* in fig. 82. This provision is known, as we have explained in connection with this figure, as the "camber" of a beam, and the amount is such, as there stated, that when the beam is placed in position and supporting or carrying its load or weight, the deflection caused by the pressure brings down the beam to the level or straight line, as at *c* in fig. 82 (in text).

In fig. 4, Plate IX., we give the details of the parts of beams trussed with wrought-iron tension rods, as in preceding figures above described. The diagram *a a f l g* shows in section the central part of a beam, as at *b* in fig. 5, Plate IX., in which *g* is the tension rod

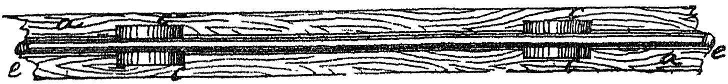

Fig 84.

passing round the head *h* of bolt *d*, secured up by the nut *c* resting on the pressing plate, as shown. The lower diagrams show two methods of securing the upper and outer ends of the tension rods *f* and *g*. In the first to the left hand, *p p* is the beam, *q* the tension rod or "tie." To adjust the nut, as the end *s* of the beam is at right angles to its length or squared off, and as in all cases the pressure or strain brought on the tension rod *q* must be in the direction of its length, if the same nut as *t* in the pressing plate against which it rests were placed against the square end *r* of the same beam *p p*, the strain on the rod *q* would obviously be out of the line of its length

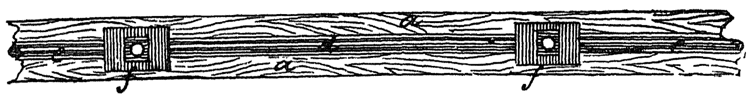

Fig. 85.

The face of the pressing plate *s*, against which the nut *t* is jammed or screwed up, must therefore be at right angles to the line of direction of the tension rod *q*. This is effected by giving the form to the pressing plate *s*, as shown, which, flat on the one or inner side against which the end of the beam *p p* presses, and angular or oblique on the other or outer side, enables the strain put on *q* by the nut *t* to be in the proper direction, face of *s* being at right angles to *q*. Where the pressing plate is flat, as at *w* in the lower diagram to the right-hand side, the end of the beam *v* must be cut obliquely, so that its face is at right angles to the line of direction of tension rod *y*. In some cases no pressing or jamming-up plate is used, the

nut pressing only upon the face of end of beam; in which case the end of beam must be cut obliquely, as shown at *v w*. But the practice is not to be recommended: a pressing plate should always be used, and that of as large a surface as possible. For it is a maxim in all good and sound mechanical construction that all pressures should be distributed over as wide a surface as possible. Hence, if no pressing plate is used, the nut, as *t* or *x*, must be unusually large in cross-section—out of all ordinary proportion to the bolt or end of tension rod, so that a broad base is given to it. In place of the arrangement for central bolt and head shown in fig. 5, Plate IX., and fig. 10, Plate VIII., and at *a d h* in fig. 4, Plate IX., the arrangement shown in last figure to the right of the upper diagrams is used for large trussed beams. In place of a bolt and head, as at *d h*, the beam as *i i*, diagram to the right at top of fig. 4, Plate IX., is embraced by the upper part, *j j*, of a cast-iron strut or bracket, shown in section in diagram below to the left hand at *i″ j″ j″*. The bracket or strut is continued downwards from *l*, where it joins the head *j j*, and is

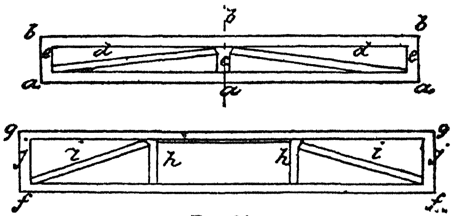

Fig. 86.

terminated at its lower end, *m*, by a part *n*, round the lower and rounded edge of which the tension rod *o p* is bent. This edge of the part *n* is hollowed out. as shown in side view at *n′*, so that a recess or hollow is made, into which the tension rod as *o′* passes, and is prevented from slipping sideways. In fig. 7, Plate IX., we give on larger scale the side view of a beam trussed in this way, in which *a a* is the beam, *b*, *b*, the struts or brackets bolted to the beam, as shown also at *k* in fig. 4, Plate IX., *c c* the horizontal part of the tension rod, bending upwards at either side, *d e*. In this form the outer and upper ends of the tension rods, as *d*, *e*, may be secured in a different way from that illustrated at *p p*, *u v*, in fig. 4, Plate IX One method is illustrated in fig. 7 at *e f*, *f* being a cast-iron box or clip embracing the end of the beam, in the recess of which the beam rests as at *i′*, *j′ j′* in fig. 4, and provided with a "snug" or projecting lug *f*, to which the end of the rod *e* is secured, the end being furnished with an eye through which a bolt is passed connecting it with the "snug" or lug, and secured by a nut.

Trussed, or as they are often called open trussed girder beams, are sometimes formed wholly of timber. In figs. 86, 87 (in text), we give various forms, of which we shall have more to say in succeeding paragraphs. In fig. 86 the upper diagram is on the "king post" (see Roofs), the lower diagram on the "queen post" principle. These arrangements assume as a whole the forms of rectangular structures, as does also the lattice-trussed beam in the upper diagram in fig. 87. In the lower diagram the beam assumes quite another form.

Some Points connected with General Framework.

Having in preceding paragraphs illustrated and classified the various forms of joists used by the carpenter in the construction of framework, we now proceed to illustrate the various classes of that frame-work, or—to use the more frequently employed term—framing constructed of timber. Those classes of framing most generally used are exemplified or met with in house construction, and are known

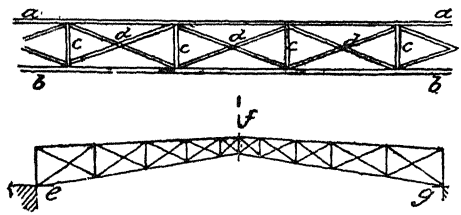

Fig. 87.

as floors, partitions, and roofs. But, in addition to these kinds of framing, there are several varieties met with in what may be called general work, such as the various forms of scaffolding and timber bridges, and that wide class of work in which the labour of the carpenter is combined with that of the mason and the engineer and machinist, as in harbour and dock work, canals, railways, and mining; and in the various classes of work in which the mason and the engineer or machinist are concerned. We propose to give one or more examples of each of these various departments of construction, so as to afford to the student of this important class of timber framing as wide a series of examples as our space will admit of, which will serve him in a directly useful way as a guide to his practical work of the future, either as examples to be directly followed, or as affording suggestions for designs of his own.

Previous to entering upon the description of these various classes of timber framing, we deem it right to give a few remarks on some essential points connected with the execution of framing. These

remarks are chiefly connected with vertical framing, such as partitions, roofs, scaffolding, etc., but are more or less applicable to all kinds of framing, as floors and horizontal construction. In order that two pieces of wood which meet may give to each other a mutual support without either of the two having a tendency to make the other turn on its axis, or, to use the popular expression, "on its side," or to "turn over," it is necessary that the axes of the two pieces should pass through a common point. It follows that the axes of two pieces of wood joined one to the other should be in the same plane, and that, with rare exceptions, their general plans or surfaces are in planes parallel to that of the axes, and consequently the faces of the assemblage or combination are all normal to these same planes. This system, whatever besides may be the forms which result from the combination of the pieces, constitutes a species of framing which takes different names according to the different positions in which it is employed.

If the joints were cut with rigorous precision, all the pieces of a framing erected vertically would work exactly in the plane of their axes, and the system would remain in a state or condition of complete equilibrium. But, notwithstanding all the care that may be taken with the work, we cannot hope for such perfection; besides, lateral thrusts created by the general building or structure itself exert upon a framing a strain or strains which tends to make it lose its proper form, and would inevitably overturn it if it were not supported by other parts which cross it, prevent it bending or leaning in any way, and secure for it perfect stability. Each framing representing a plane surface, it will be easy to draw it, pointing out on the drawing itself the actual length of the pieces which compose it.

In drawing the plan of any framework, the simplest and easiest process consists in imagining at first that the component pieces we desire to use are inflexible rods, possessing neither width nor thickness—that is, mere lines. We draw in reduced proportions, and separately, the partial plans of the different framings, by simple lines which represent these lines on the axes of the pieces. Among the figures which result from the combination of the lines in each drawing or framing, there are some which should in the first place suit the forms which the destination of the construction requires. Other figures, which are of no slight importance in the plan, should insure the stability of the construction. This drawing should show the position of the pieces of wood which should be common to the different framings which cross each other in the general design, if more than one. The principal lines of the plan being thus established, we add to it those which represent the auxiliary pieces, having as an object

either to multiply the number of the numerous points which add to the rigidity of the framing, or to strengthen some parts which the flexibility of the wood would render too weak, or in short to distribute the strains or pressures so as to meet or resist certain strains, or transmit them to strong points capable of resisting them. When we have thus satisfied all the conditions, and in all the framings, by linear plans made and drawn on a scale proportioned to the clearness of the details which we must afterwards add to it, we draw, by other lines parallel to the first, and on the same scale, the thickness of the different pieces, in order that they may have the strength required by their situations and the functions they have to fulfil, commencing with the most important or those which are the highest, and which have the least strain or the least weight to support. The drawings which this first work gives correspond to those which architects call plans and sections, and are made according to the principles and practice of descriptive geometry. These drawings, figuring carefully all the necessary dimensions, to fix exactly the position of all the pieces and point out their general relations, usually suffice to guide the carpenter in forming the projected framework.

In general, the pieces of wood used in carpentry are not prepared with such precision that we can, as in other departments of construction, trace on their surfaces by rule and compass, or by templates or models of full size, lines which should determine their dimensions in length and the position of the joints. The pieces of wood are of a shape, size, and weight, which do not admit of moving them easily and turning them in all directions, as rendered necessary by the number of operations required. Besides, in drawing each piece independently of those which should be joined to it, we should introduce into the position and the shape of the different joints errors or mistakes which it would be almost always impossible to correct when they were placed *in situ* or in position. In the art of the carpenter there is therefore a method of drawing on the large scale similar to that employed by the shipbuilder, in which no joints are drawn with precision. He draws upon a large surface—in the art of shipbuilding it is called a "drawing-floor"—the design of the framing in full size. This drawing is often called by the name of "the lines" or the "working lines" of the design, as it contains only the lines which are strictly necessary; these lines are the axes of the pieces, or the reproduction on a large scale of the linear plan which we have already alluded to.

In order that the axes of the pieces should be exactly vertical to the lines which represent them on the "working lines," it is necessary that these axes should be drawn on the pieces of timber forming

this framing. This operation is effected by means of a line. In a framing, as for example a partition, the pieces of which should be exactly square, the lines of junction should be straight and perpendicular to the plane of the axes of the pieces, and to each of their faces which are parallel to them.

We have further to remark that consequently, if a partition, whatever otherwise may be the position which it is to have in a building, is supposed to be inclined horizontally, so that the plane of the axes of the pieces of timber which compose it is level in all directions, all the lines of junction are vertical, and a plumbline, which can be applied and which coincides perfectly with them, is tangent at the same time to the two normal surfaces, which form by their meeting these lines of junction.

It is upon this observation that the principle of setting out the work of framing is founded. Consequently, to proceed to the setting out of a framing, as for example that of a partition, we fix all the pieces of which it is to be composed precisely perpendicular upon the places that they are to occupy in the framing, and which we have already marked on the drawing floor in full size. We place these pieces one upon the other, crossing them according to the plan, and of the length necessary for the plan of the joints; the normal surfaces of all these pieces are in the same vertical planes that they will occupy when joined in the horizontally inclined side.

We see, then, that it is easy to mark on the normal surfaces the lines of junction; for they are the mutual outlines of the prolongations of the planes in which these surfaces are found. We can thus easily trace these lines of junction by the aid of a plumbline or the square, which will be at the same time tangent to the two surfaces which are to be joined, and which will coincide on each with the line of junction which is to be traced on it. This position is then marked by two points pricked or traced on each surface with the point of a tracing point or spring bit. This process, which is at the same time the most exact, establishes in the work a perfect order which economises much time. The carpenter then proceeds to the making of the joints, which no longer presents any difficulty, and according to the methods described in preceding paragraphs.

If the same framing is to be repeated several times in the same building, the carpenter generally makes use of the same working lines laid down in full size upon the drawing floor or ground, taking care to set aside the framings already made, after having distinguished each of their pieces by a particular mark, in order that in the operation of building or setting the framework up we may not confuse them with one another.

The commonest system of marking is that in which we make use of capital letters and Roman numerals. The letters other than Roman are employed in preference to mark with the same letter all the pieces of the same kind, in order not to confuse them with the numerals which serve as data for the joints, and which may be called counter-marks. Other lines may be also adopted to mark the top, the bottom, the right, the left of the framings, in order to recognise more clearly the position that each piece should occupy when set up in position in the building or structure.

Special Framework.

"Floors" serve to form the areas of the different stories of a house. They are generally composed of "beams" or "girders" or "binding joists," and flooring boards or planks. Beams or girders are strong pieces of wood, the ends of which rest on the walls. Binding joists are pieces of smaller dimensions jointed transversely to the beams, and the "joists" are still smaller in section, and support the flooring boards or planks forming the walking surfaces of the floor. Sometimes floors are made without beams, but in that case it is necessary to increase to a certain extent the dimensions of the joists. The flooring boards vary in thickness and in width from 3½ to 5 or 6 inches; they are secured side by side on the joists, and in this way the upper part of the floor is made. Methods of laying flooring boards come generally under the work of "The Joiner" (which see). Floors or floor framings are of three kinds or classes. The first kind comprehends "single floors," composed of parallel joists resting by their ends upon the walls. There are no beams or binding joists in floors of this kind. The second comprises floors composed of "binding joists" resting upon the walls, and the ordinary joists placed transversely upon these. In the third class of floors there are three distinct kinds of members: first, heavy beams, generally called "girders," which rest upon the wall, either built into it directly, or resting in and upon stone templates or cast-iron boxes built into the wall in the manner hereafter to be explained. Those girders or large-sectioned beams themselves support or carry "binding joists," which run in a direction transversely or at right angles to the girders. Those binding joists carry the ultimate member of the floor —namely, the ordinary flooring joists. In all the three classes of floors the flooring "boards" finish the work. This part of it comes more properly, as we have said, under the category of joiner's work, and so also the construction and fitting of the "skirting board" or "dado," these being constructions designed to give a finish to the floor and the room by concealing the void space left all round the

floor where it joins and is terminated by the walls. We shall now describe and illustrate in detail the three classes of floors we have just described in a general way. These three classes, the reader will perceive, are in ascending order, the first named being the simplest and used only for floors of small plan or narrow widths between the walls, the second for heavier floors of greater span, the third for floors still "heavier"—this being the technical expression generally used—and of the largest span or width between the walls or points of support.

Taking them in this order, we now proceed to illustrate and describe the simplest form, which is known as "the single floor." This is illustrated in plan—and section in the lower part of diagram—in fig. 1, Plate VII. In this *a a a* represents the wall of the building, *b, c, d* the "joists" running parallel to one set of walls and at right angles to the other. They are equally interspaced over the floor surface or void space between the walls—that is, the intervals between each are equal: a very usual distance being 14 inches from "centre to centre," this technical phrase indicating that the distance is measured from a line running down or imagined to be running down the length of the joist in the centre of this thickness or breadth of edge, so that the actual space is always less than the "distance from centre to centre" by a width equal to the thickness of one joist or twice the half-thickness. In spacing the joists, the first joist is often laid close to the wall or laid on an "offset" formed at the point where the thickness of the wall of an upper story is reduced from that of the story below: this is done to give a support to the flooring boards quite close up to the walls. In other cases the first joist starts at a distance less than the interspace from centre to centre of the joists over the general surface of floor, as shown in fig. 1, Plate VII. Timbers should never be built in or inclosed wholly within the brickwork or stones of a wall, as at *b b*, as they are sure to be affected with the dry rot, a disease to which timber, placed even in the best of circumstances, is but too liable. Timbers in a building cannot be too freely exposed to the atmosphere. Building-in timber cannot, however, be avoided in many cases, as in ordinary floors, as in fig. 1, Plate VII., in which the "joists," as *c c d*, must rest upon the walls *a a* to find points of support. They do not extend to any distance beyond the walls, or even up to the outer sides of these, but stop short of this, the lengths of the parts resting upon the walls—technically called the "bearing"—varying from one-third to one-half of the thickness of the walls. In cheap work, in order to save timber in the length of the joists, the "bearing" is generally the minimum. In cheap work the "fineness" to which

items of construction are "cut down"—to use the slang expression commonly in use—can only be understood by those who have had practical experience of "contract work." In fig. 1, Plate VII., we give the plan in A, and section in B, fig. 2, of a single floor, in which *a a* is part of one of the walls, *b b* the flooring joists, on which rest and to which are secured flooring boards, *c c*. In fig. 2, section in diagram B, the floor is supposed to be that of the lowest or ground-floor story of the house, *a′* is footing of wall, *b′*, *b′* "joists," *c′* "flooring boards," *e′ e′* ground line. Letters of reference indicate the same parts in both diagrams A and B.

In the second class of floor—the "double floor" illustrated in plan, fig. 3, Plate VII., A, and section B in same figure—a third member is added: the "binder" or "binding joist" or "binding beam," as in diagram A, fig. 3, same Plate; plan *a a* part of wall on which rest the "binders" *b b*. The better plan is to support the binders on small piers run up from the ground to floor level at *c c* in plan. The distance between the "binders" or binding joists, as *b′ b′*, varies according to circumstances from five up to seven and eight feet: the distance in illustration is marked five feet. On the binders rest the "joists" or "flooring joists" *c c*—these running often at right angles to the line of "binders"; and on the joists the "flooring boards" *d d*, parallel to the binders.

In the third class of floor—the "double-framed floor"—illustrated in fig. 1, Plate V., and in diagram A, plan, and section diagram B, a fourth member is added: the "girder," often distinguished as the "beam"; the members in the two preceding classes being in this case all termed "joists," as "binding joists" and "flooring joists" In fig. 1, Plate V., *a a* is part of wall, *b b* the "girder" resting at the extremities on the wall in an aperture or cavity formed therein, but larger than the section of beam, so as to admit air to the end of the beam. The distance between the girders varies according to circumstances: ten feet is that marked in the drawing. The "binders" are framed or jointed into the girders, and run at right angles to the same. On the "binders" rest the "flooring joists" *d d*, and on these the flooring boards *e e*. The section B, fig. 1, Plate V., is that taken as looking at plan A in the direction of arrow *f*, fig. 2, Plate VII. Where ceilings are placed below the floor "ceiling joists" are used, to which the lath and plaster are secured. There are small-sectioned joists or battens jointed to the under side of the joists in the case of "single," to the "binders" in the case of "double," framed floors—sometimes to the girders themselves in the latter. *g g*, fig. 2, Plate VII., A and B—which latter is a sectional side view of A in the direction of the arrow *f* in A—show the "ceiling joists."

In some floors the "ceiling joists," as *g g* in fig. 2, Plate VII., are carried by another member called "ceiling binders": those are illustrated in figs. 3 and 4, Plate II., which are two views of the assemblage of timbers in a floor, say for a width of space or span of 16 to 18 ft. In fig. 3, Plate II., which is a view in the direction of the flooring joists, *a a* indicates the "flooring boards" $1\frac{1}{4}$ in. thick and 9 in. broad or wide. They are shown as laid down in three ways of jointing, the joint at *a*′ being the simplest of all, termed the "butt joint," the edges of the planks or boards being faced or squared up and the surfaces planed, the edges being then "cramped" or forced or jammed up close to one another. Another form of joint is shown at *a*″, which is termed the "tongued and grooved joint," the edge of one board being provided with a rib or "tongue" in the centre of its thickness, the edge of the contiguous board being provided with a recess or groove also centrally placed. When the boards are "brought up" the tongue enters the groove and makes a joint, up which, if tight and well made, the cold air from below does not so easily pass as in the "butt joint" at *a*′. Another form of joint for flooring boards is shown in same figure (3, Plate II.) at *a*″, in which the edges of both boards are grooved, and a "feather" or narrow stip of wood sufficient to fill the space between the two grooves is inserted when the boards are faced or brought up to each other.

In fig. 3, Plate II., the flooring boards *a a a* rest upon the "flooring joists" *b b*—11 in. deep and $2\frac{1}{2}$ in. thick—spaced at intervals of 14 in. "from centre to centre." Running in the same direction as the flooring joists are the "ceiling binders" *c c*, into which the "ceiling joists" *d d*, $2\frac{1}{2}$ in. thick by 4 in. deep or broad, are notched, as at *e*. Another method of jointing them to the binders is shown in fig. 4, Plate II., which is a cross-section of fig. 3 in same Plate, in which the flooring boards *a a* are seen to run the long way in place of transversely as at *a*. The letters of reference are the same in both figures. The joint of ceiling joist to ceiling binder is shown at I; a front view being shown in part section of the assemblage to the right of the diagram at point I′. In both drawings *c c* indicates the position of lath and plaster ceiling.

In fig. 2, Plate V., we give an enlarged drawing on the same scale as figs 3 and 4, Plate II., are drawn to—namely, $1\frac{1}{2}$ in. to the foot, or "one-eighth scale"; showing in cross-section the assemblage of timbers in a "double-framed floor," with method of jointing used in connecting the "binder" or binding joist with girder,—in cross-section in the diagram A, in part side view in diagrams B and C. The "girder" or "beam" is shown at *a a* in A; part of the binding

joist as it is carried at each side of the girder at *b b*. The joint is shown at the points 1, 2, and 3. In B *a′ a′* is the girder, *b′ b′* the binding joist, in side elevation, with the joint as 1′ 2′ 3′ cut out in its face. In C the "flooring joists" *d* are shown in cross-section at *d*; ceiling joists at *e*. This floor is suitable for a space of 18 to 22 or 24 ft., and the following are the scantlings or dimensions of the parts: girder *a a a′ a′*, 13 or 14 in. deep by 8 in. thick or wide; binding joists or binders *b b* or *b′ b′*, 11 in. by 6 or 6½ in.; flooring joists *d*, 11 in. by 2½ in.; and ceiling joists 4 in. by 2½ in. Figs. 1 and 5, Plate VI., show a framed flooring taken from Continental practice.

Trimming Joists or Trimmer Beams.

"Trimmer beams" are employed when openings or void spaces are to be left in floors, breaking the continuity of the flooring joists. In figs. 1 and 2, Plate X., we illustrate on large scale—one-eighth—that part of a floor near a fireplace, in which what are called "trimmer" joists are use. The object of the arrangement is to give a support to the hearthstone of the fireplace, and in good and sound construction to the trimmer arch of bricks upon which the hearthstone is laid. It is essentially vicious construction to place, as is often done, the hearthstone right upon the joists. This is a fruitful source of mischief, as the hearthstone gets frequently overheated, as by taking off a mass of glowing coals at bed-time, and the joists below are thus ignited. The beams or joists of a floor in good construction are arranged as follows. In fig. 2, Plate X., part of the plan of a floor is shown in which *a a* is part of the outside wall, with projecting jambs, *b*, *c c* being part of the chimney flue coming up from a story or floor below. The ordinary joists or flooring joists stop on either side of the fireplace jambs. The trimming joists or trimmer beams are at the side of the jambs, as *d d*, *e e*, in fig. 2, Plate X.; in good construction the ends, as *f*, *g*, rest upon stone templates or plates, *j j*, built into the brick wall. The ordinary flooring joists, as *i i*, which are exactly opposite the fireplace and between the trimming joists *d d*, *e e*, do not come up to the fireplace, but stop short at the cross trimmer beam *h h*, which is called the "carriage beam," its purpose being to carry the ordinary flooring or common joists, one of which is shown at *i i*. The two joists, as *d d* and *e e*, which support the carriage beam, as *h h*, are called "transverse joists," and they are made stronger than the ordinary or common joists, as *i i*, as they have to carry the carriage beam, *h h*, and as many of the joists, as *i i*, as the breadth of the fireplace and its hearthstone demands. In fig. 2, Plate X., we give a section drawn to same scale as fig. 1 (1½ in. to the foot, or

one-eighth scale) of the assemblage at the trimmer of a floor. In this the letters of reference as in fig. 1 indicate the same parts. The parts not shown in fig. 1 are the elevation of the brick trimmer arch on which the hearthstone rests, as shown at *k k*.

Floor Strutting.

When the reader has studied what will in future paragraphs be given on the subject of the strains or pressures to which framing is subjected, he will understand how the flooring joists, both in single and framed floorings—the "double" and "double framed" classes being generally classed under the general title of "framed floors"—are apt to give way laterally to undue pressures. This is a great source of weakness in a floor, and is greatly aggravated, as the reader may understand, when the joists are made unduly weak. And from what we have already said, there is a great temptation—too readily in some, we might say many, cases given way to—in the case of cheaply constructed houses chiefly of the class of cottages, to make the flooring joists much too weak, in order to save the small sum which a greater and the necessary strength would cost. To obviate the tendency of all flooring joists to "give" laterally to pressures, and to make them stable and free from that shaking and tremor with which many are too familiar in their houses what is called "strutting" is employed. This is of two kinds—the simplest being merely flat pieces of thin wood of the depth of the joists, or often less, jammed in between the joists; care being taken to keep them in line, so that the pressure communicated to one shall be distributed throughout the series. The position of these "struts" is shown at *d d* in fig. 1, Plate VII. A more expensive, but much more effective kind of strutting is that known as "cross," or "herring-bone." This is illustrated in fig. 1 in cross-section, and in fig. 2, Plate XI., in plan. In fig. 1 *a a* represents part of the beam or girder, to which the flooring joists *b b* are jointed. These are shown in cross section, and between them the struts, as *c c*, are crossed, one end at the foot, pressing against the joist near its lower edge, the other at the top, near the upper edge of joists *b b*. Another strut, as *d d'*, is crossed in the reverse direction and in the same position,—this, of course, being made up of two halves; one, as *d*, being at the upper side of *c c*, the other, as *d'*, at the lower side; *e* and *f* show part of two pieces. The struts are placed in line, as shown in plan, so that the pressure is distributed from one to the other. Strutting of both kinds is often made of too thin pieces: no doubt, as the strain to be resisted is that of compression, thin boards can resist a large amount of it; but as the naturally

small cross-section of their struts gives a small bearing surface to rest or press upon the sides of the joist, they are apt under heavy or sudden pressures—as in dancing or moving very quickly over the floor—to spring, and get moved out of their true, that is vertical, position, and also out of line one with another. Sufficient thickness should be given to plain strutting, as at *d d* in fig. 1, Plate VII., to give a good bearing on the face of the joists, and sufficient breadth in the case of the cross or herring-bone strutting in figs. 1 and 2, Plate XI.

Framing of Floors—"Deadening" or "Deafening."

In order to deaden sounds proceeding from a room below to one above, as also to strengthen them, floors are strutted horizontally with continuous flat boarding, which serves as a support or a species of floor upon which the "deadening"—or "deafening" as the work is more generally called—materials are placed. In fig. 3, Plate XI., we give cross-section of a "deafened floor," and in fig. 4 plan of same, these drawings, as well as those in figs. 1 and 2, same Plate, being given to a scale of an inch and a half to the foot or "an eighth scale." In fig. 3, Plate XI., *a a* are the flooring joists in cross section carrying the flooring boards *b b*. To the sides of the joists *a a* narrow and thin battens, *a a*, are nailed, running along their whole length. These afford ledges or supports on which thin boards, *d d*, are placed and nailed down, as shown in plan, fig. 4, Plate XI.; and upon those boards, as a species of floor, the deadening or deafening material, *e e*, is placed. This may be common mortar well mixed with hair,—or if the floor is designed to be largely fire-proof, a cement concrete may be used, the best cement to use being "Portland." In the plan fig. 4, Plate XI., the same letters of reference refer to similar parts in fig. 3.

Sleepers or Templates and Bearing Walls for Beams.

In a preceding paragraph we referred to the danger of dry rot likely to accrue when timbers are inclosed or built into walls. This, of course, is likely to be attended with graver results in the case of timber of large size, on which so much depends, than in those members of a floor of less dimensions. Hence, in the case of beams or girders it is good practice to avoid the building of them into or inclosing them by the wall material, brick or stone. This is avoided in one way as represented at *j j* in fig. 2, Plate X. In fig. 2, Plate X., *j j* is a flat stone, four or six inches deep, the thickness proportioned to size of beam or girder, laid on the wall at the point

at which the girder terminates. The stone should be considerably broader or larger than the thickness of the girder, so as to give ample bearing surface. This stone, called a "template" technically, is surrounded with an open space a little higher than the depth and a little broader than the thickness of the beam or girder, so as to form a species of box or cavity, into which the end of the girder enters, resting upon the template as a bearing surface, and affording free access to the air all round the end of the girder. When the stone template is used without the cavity or box formed above it, it only acts as a good bearing surface for the girder, distributing its weight over a larger surface of the wall than it would if it merely rested upon a brick or two (this contrivance being, of course, only used in the case of brick walls); in the case of stone walls it is obviously easy to select a large-surfaced stone to place at that point in the wall at which the beam or girder rests. But this distribution

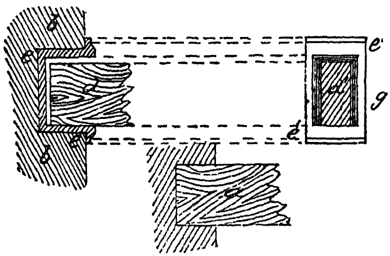

Fig. 88.

of pressure on a wall is a point of such importance, that in good and sound construction it is always attended to; hence if the template and box or cavity be not together used in the case of large beams, the template alone should not be omitted. The two are best; but the template, as a good bearing and pressure-distributing surface, is better than merely resting the beam with all its weight upon a brick or two. In some cases cast-iron "girder boxes" are specially constructed and used for "housing"—such is the technical term used —the ends of heavy beams. This is illustrated in fig. 88. In this *a* represents the ordinary and vicious way of building in the end of the girders into the wall *b b* The approved and sound method of having a special girder-box most conveniently formed of cast iron is shown in the same figure, *b b* being the wall into which the cast-iron box *e e* is built, *d* being the termination of the beam or girder. A front view of box is shown at *c′ c′ d′*.

Air-Bricks, etc.

In all good construction every care is taken to prevent, if possible, the ravages of "dry rot" in the timbers; although, notwithstanding all the care taken, this insidious disease in timber cannot be prevented —is never, or rarely, cured when once it sets in. The best known, at least the simplest and, upon the whole, the most generally effective, system which can be adopted, is so to arrange the timbers that they are exposed as freely to the atmosphere as is possible under the circumstances; for keeping timbers in a close, confined, and damp or dampish atmosphere is the best way to secure dry rot, or at least to bring about a tendency to it. As it is in the timbers nearest the ground in which dry rot or decay is most likely to occur, the condition most favourable to it being met with there much more certainly than in the higher situations, as the floors of upper stories, it is the usual practice to build in what are called "air-bricks" into the walls near the ground level, so that currents of air can be established through the space below the flooring. These air-bricks, although so called, are often of cast iron, but as they are made of the same dimensions as an ordinary brick, to "bond" with the general work, the name is appropriate enough. The sides of these iron air bricks form a species of grating, through the apertures of which the air passes from the external atmosphere to the void space below the floor, thus circulating amongst the timber. Air-bricks are, however, specially made of the usual clay, or rather of earthenware, vitrified or very hard, and built in the same as cast-iron air-bricks. The use of these appliances for ventilating the spaces below the floors is greatly objected to by some householders, as they cause such a constant current of air through the flooring boards and up the vacant spaces left at skirting boards, etc., that the room is kept cold and "draughty." This is owing to defective work in laying the flooring boards; and it is simply a question between having good work to prevent this cause of personal discomfort to the occupiers of the room, or to stop all ventilation below the floor, and thus increase the risk of dry rot in its timbers, with all its attendant evils. It has happened before now that floors have had to be taken up, so unsafe had they become through the ravages of dry rot and from the lack of timely supervision and the application of remedial measures, and serious accidents have taken place. And what has happened once may happen again, and prevention is better at all times than cure, if indeed in this case cure be within reach.

In addition to the air-bricks for supplying air generally to the spaces below flooring timbers, in good construction care is taken to avoid as much as possible the building-in of timbers at their ends or

bearing points into the walls. Piers of brickwork are often run up between the outside walls on which timber plates or sleepers are laid, these carrying the joists. These greatly strengthen the floor, while the sleepers are freely exposed to the atmosphere, so doing away with the necessity to give such a deep bearing to the joists on the outside walls and thus lessen the length built into or inclosed by them. By carrying up a pier close to the wall, the building-in of the ends may be done away with altogether, the joists being already supported by the piers and sleepers or plates. But the usual way is to carry up as part of the "footings" what is called a "sleeper wall"—that is, a part so projecting from the normal face of the wall that a ledge is formed, on which the ends of the joists rest, freely exposed to the atmosphere, and not built in at all in the general wall. This is shown in fig. 2, Plate II., in which *a a* is the end of a joist built into the wall in the usual way, but by carrying up the footing *c*, as in the line *d d*, to the level of the flooring joist line, it is obvious that a ledge *d b* will be formed, which will be the bearing surface of the joists. As the footings are generally formed by "offsets," as *e f*, of half a brick—four and a half inches—only, this would be narrow enough as a bearing for the joists, but a broader ledge for a longer bearing of the joists can be obtained by carrying up the footing *e f* as at *d d*. Sleeper walls will, of course, be objected to in cheap houses as being too expensive, but wherever sound construction is desired more than the saving of a few shillings, they should be given. The method of housing heavy timbers is shown at *j j* in fig. 2, Plate X., as explained in connection therewith, and by the use of cast-iron girder boxes, as named in last paragraph, and used in upper stories; but piers and sleeper walls should in such cases always be used as named above

Where the shape of the apartments of a house does not give rectangles or squares—that is, with the walls at right angles to each other—a little complication arises in the distribution and fixing of the timbers; and where the floor space is extensive or spans wide, the timbers have to be carefully arranged, and braced so as to distribute and bear the extra strains thrown upon them. As illustrative of these two cases we give drawings in fig. 1, Plate XII., and fig. 1, Plate IX. In fig. 1, Plate XII., which is the plan of an irregularly formed apartment, *a a* represent the lines of girders or beams, *b* those of joists, *c c* the trimmer beams, *d d* the trimmer carriage beams, *e e* fireplaces, *f f* staircase, *g g* joists of small room. Fig 1, Plate IX., is the drawing of a floor used on the Continent, in which the timbers are braced by regular pieces, as shown.

It is necessary carefully to avoid resting the beams above the

vacant spaces formed by the doors or windows of a house. A beam should, as far as possible, rest upon a solid wall; if otherwise, one must take precautions to avoid the disadvantage of an accident or undue settlement. In this case, under the beam a horizontal piece of timber, called a "lintel" is placed, which rests on the length of the wall, having a good long bearing at each end. This lintel serves the same purpose as the breast-summer or bressumer in a partition. But it is still better, when space permits, to support the beam upon a small arch, generally known by the name of a "relieving arch."

These floors, such as in fig. 1, Plate VI., are formed of pieces which, in general, do not cross from one wall to the other, but are joined together and support each other. Their arrangement may be varied *ad infinitum*; for it depends not only on the form of the building, but also on the length of the pieces, which is often less than the interstice of the walls As these floors are more complicated and more difficult of execution than the others, it is obvious that we should have recourse to them only in exceptional circumstances. We shall see, when treating of the carpentry of roofing, some examples where floors of this kind must be used. Care must be taken in such floors not to weaken too much the heavier pieces, to which are jointed the smaller pieces, by unnecessarily multiplying the mortises or putting them too near one another.

It is to be observed that the braces, as *a*, fig. 1, Plate VI., are placed in such a way as to receive the beams *b b*, corresponding to the hip rafters of a roof (see Roofs), and to be joined at the same time to the girder *c c* and to the tie *e e*. As these two pieces must bear the whole weight of the floor, the other pieces must be joined to them in such a way as not to weaken them too much by joints. Care must be taken not to place the binding-joists in the bays one opposite the end of the others, but alternately breaking joint, as it were.

Partition Framing.

Taking the timber work of a house in regular sequence, and having in preceding paragraphs described and illustrated the various forms and classes of floors, we next come to the subject of partitions. Properly—at least if safety from fire, if not security and soundness in construction be considered—all partitions (that is, the walls which divide one apartment from another) should be of brick or stone. The massiveness of stone would, save in the case of large buildings, however, preclude its use as a general rule. We find, therefore, in houses of the ordinary classes of domestic structures, where stone is employed almost universally for building—such as in the northern districts of England, in Yorkshire, and throughout Scotland—if

the partitions be made of imperishable or rather of incombustible material, that brick, being the lighter material, is almost invariably used for partitions. And it is this indestructibility by fire which demands that it should be used in all buildings which it is desirable to have fire-proof as far as possible. And if there be one class of structures in which this desideratum be required more than in another, assuredly it is in the domestic structures in which we habitually live, and run of necessity specially great risks in the helpless hours of night.

In all well-designed buildings the partition walls should be carried right up to the roof, and in place of stopping short, as they almost universally do, at the level—that is, the horizontal line formed by the terminating surfaces of the walls—if they were carried farther up to meet and to take the form of the roof section at their various points—there can be no doubt in the minds of all those connected with construction that a great step would be taken to secure danger from fire. Certainly one great advantage would be gained by this simple, if comparatively inexpensive plan—namely, that fires would not spread with the fearful and the all too dangerous rapidity they almost invariably do. Time at least would be given for the inhabitants to escape with something more than their own lives—although lives are not seldom lost—and time by consequence given to bring forward means for extinguishing the fire, which now but too often arrive too late to save the building in which the fire originated, and only in time to prevent it spreading to other structures near or joined up to it.

And of all the means by which fire is spread or rapidly communicated from one part of a building to another, it is admitted on all hands that timber partitions are unfortunately but too well designed to act as the most efficient. Not only constructed of a most perishable material throughout—their very design makes them but as hollow compartments, which, as has been well observed, act as "mere chimneys," by which flame and heated gases—which themselves are active agents in combustion—are carried up from a low to a high level; so that floors and roof above are speedily set fire to in cases where the fire breaks out in one of the lower apartments. But even where the contrary is the case, the partitions still serve but too efficiently as conveying fire even from an upper to a lower apartment.

Seeing, however, that timber partitions still hold a very important place in building construction, and are likely for long to do so—so difficult is it to substitute for an old-established and defective practice one which is admittedly much better at least, if not altogether perfect—we are of necessity, as it were, compelled to notice them in

order to make our paragraphs on the practical work of carpentry complete. We see, then, that partitions are a species of wall or division of wood, used in countries where wood is cheap, or where long custom has established its use; and sometimes also, it is right to state, where from particular circumstances we wish to give less weight to certain parts of a building—as, for example, when in a building a partition is supported by a beam spanning a room below. In many districts, moreover, and throughout the United States of America and in our Colonies, houses are constructed of wood. The pieces of timber-work of which they are composed are roughly set up. But sometimes wood is used for light and elegant constructions which contribute to the decoration of pleasure gardens. In every case, however, the carpenter should pay attention to the rules of the art; and as it is principally in the quality of the joints and the arrangement of the pieces that the merit of the work consists, what we are now about to say regarding timber, exactly worked, "wrought," or squared, will apply to all analogous work in framing, whatever may be the choice of the materials employed.

When we come to the considerations of the principles of framing we shall see that there is a general principle in timber-work, and one which must never be deviated from—viz., that all the pieces should be arranged in such a manner as to form between them a series of triangles. A triangle is a perfectly rigid figure, which practically cannot be put out of shape by any strain. We may break a triangle, but we cannot change its shape, whatever pressure we may bring to bear upon it. The other figures, on the contrary, are only kept up by the strength of the joints. Thus, in a quadrilateral or rectangle the angles can enlarge or contract without the sides changing in length; and the joints have much to bear as soon as any strain whatsoever happens to weigh upon one of the angles of the figure. It is necessary, then, that the joining of the pieces should form a series of triangles; the only exception to this rule is in the case of "floors," in which there is no lateral pressure or strain, but all the strain thrown upon them is vertical.

The partition generally rests upon a wall, the object of which is to separate the structure in the lower story from the ground and to preserve it from the destructive effects of damp. In this case, upon the wall rests a piece, *a a*, fig. 6, Plate XIII., placed horizontally, which is called the "sill," and which forms the base of the construction. It is in this piece that all the other pieces of the framework are joined. The vertical pieces at the ends, as *a b*, *a b*, named "posts," and sometimes called "double quarterings,' are joined by tenon and mortise to the side *a a*. These pieces should have the

height of the apartment or room in which the partition is to be placed. The separation of the ground-floor and of the first flat is made by means of another horizontal beam, *b b*, called the "head," and which is joined to the posts with tenon and mortise joints. Between the two beams, *a a* and *b b*, use vertical pieces parallel to the "posts," and which are also called "posts," though sometimes "framing-posts," as to these pieces the door fitting in space *f f* is secured. These door-frame posts, *c c c c*, form the opening of the doors, and in wooden houses the windows, as illustrated hereafter; they are joined by lintels or horizontal pieces, as shown—sometimes called a spacing piece; although we shall see presently that this is applied to another part in a more complicated form. The "posts" *a b b b*, the "sill" *a a*, the head *b b*, and the framing-posts *c c c c*, form, as we see, quadrilaterals or rectangles. These are divided diagonally by oblique pieces, *d d*, called "struts" or "braces," which decompose the figure into two triangles, each supporting the casement or door-posts. In this way there is no fear of a lateral strain throwing out of shape the whole of the work. The joining of these pieces forms the framework of a partition. The open spaces between the main timbers now described are called "filling-in pieces," sometimes "single quarterings," in contradistinction to the "posts," *a b*, *a b*, *c c c c*, which, as we have seen, are sometimes called "double quarterings." The whole work is covered with the lath and plaster which forms the wall surface for receiving the decoration of paint or paper.

We have in fig. 6, Plate XIII., given a form of partition not of the simplest kind, but have taken it to illustrate the important parts of what is called a trussed or framed partition. There are other simpler as well as more complicated forms used under various circumstances, and these we now proceed to illustrate. In fig. 2, Plate VI., we illustrate the simplest form of partition used in cottage work—to divide one room from another, or a room from the well-hole of a staircase. It usually rests upon a wall carried up from the floor below, although for obvious purposes of illustration we show it to be carried by a beam *b b*, itself carried by the walls *a a* of the main building. Parallel to this, at the height of the room or ceiling line, a light batten, *c c*, is carried across, and usually built into the wall; although it is sometimes supported or carried by vertical posts or pieces, *d d*. Horizontal pieces, lintels, or heads, as *e e*, are filled in at the level for door-head openings, of which in the illustration there are two; one as to the right, entering the room from the staircase; the other to the left, giving access to a closet or another room. Between the pieces *e e* another horizontal piece or

straining piece or brace is inserted, to support the side posts *d d*. There are no "filling-in pieces" or "single quarterings," as at *e e* in fig. 6, Plate XIII., in the form of partition in fig. 2, Plate VI., the filling-in pieces not being required, as there are no laths or plaster used in it; the paper or paint is at once applied to the boards, as *h h*, with which one side only of the simple framing pieces *c c*, *d d*, *e e*, are covered. These pieces are therefore seen at one side of the partition—and this side is naturally chosen to be at the staircase well-hole, if the partition be next it, as showing in the least important of the two rooms which it may divide. In what is called superior work of this class a second horizontal straining-piece is placed parallel to *f*. This partition here illustrated has no pretensions to being considered a framework, as it is purely rectangular, and dependent almost wholly upon the walls, *a a*, for such strength as it is able to resist laterally, and somewhat upon the posts *d d* and straining-pieces, as *f*. So also is another form of this boarding or "hoarding" partition illustrated in fig. 5, Plate XIII., in which, however, there is provision made for but one doorway, and that in the centre at *d d e*; *a a* are the walls, *d d* the door "posts," *c c* and *e e* horizontal pieces; *f f* being the boarding, which may be placed horizontally as those shown, or vertically as at *g*. In place of strengthening this by a horizontal straining-piece, as at *h*, if we throw across a piece as near *g* to the left, obliquely stretching from the post *d*, a little below the level of door "head," *e*, and butting at its lower end partly on the vertical wall *a a* and partly on the horizontal wall or beam *b b*, on which the partition rests, we at once introduce the element of the "truss," and change the simple construction destitute in reality of all the elements of stable construction or as in the form in fig. 2, Plate VI., into the more dignified because more scientific construction called a "framed partition," or a "framed and trussed partition." Of these two names the first is the more accurate if not the more clearly defined; for a "frame," properly considered, must embrace the elements of a truss. A trussed partition and a framed partition are therefore scientifically synonymous or convertible terms.

The simplest form of a "framed" or "trussed" partition is shown in fig. 4, Plate XIII. In this all the elements of a true framework are present, in which the members are so combined that it possesses the strength not only to support its own weight, but additional weight, as of a partition or a slight wall above, and that over a void "space—spanned by the sill or foot beam *a a*—without yielding to lateral pressure thrown upon it. In this *a a* is the "sill," *b b*, parallel to it, is the "head," *c c* the "posts" or "double quarterings," *f f* the

"filling-in pieces." The "braces" or "struts," as *e e*, butt at their feet against the side *a a*, and at their head against the "post" *d d*, distinguished from the posts *c c* at end by the name "principal posts" sometimes given to the latter. In this there is no door opening at all; this is, however, provided in the form of trussed partition in fig. 6, Plate XIII., at *f f*; in this case the "braces" or "struts," *d d*, butt at their upper end against the "posts" *c c*, and at their lower against the "side" *a a*, near the "principal posts" *a b*, *a b*; the filling-in pieces are at *e*. All these pieces, as in all framed partitions, are of the same depth or width, and so joined together as to present flush surfaces on both sides of the partition.

In fig. 3, Plate XIII., we give the half of another form of trussed partition in which there is a door opening at each end, as at *f*; the central part being braced precisely in the same way, as in the form in fig. 4, Plate XIII. In this (fig. 3, same Plate) the braces, as *d d*, butt against the side *a a*, near the foot of the door-framing post *e e*, in place of at the foot of the principal posts at *c c c*, fig. 4, Plate XIII., and at the upper end against the head of the post *c c* in centre of partition—the door head or straining-piece as at *f*—*g g* the filling-in pieces.

A more complicated form of partition is illustrated in fig. 1, Plate XIII., sometimes called a "double-framed quartering partition." This is employed where voids or spaces are to be spanned, and the illustration exemplifies a form in which there is in the centre an opening or void for filling in with wide folding doors—an arrangement very frequently adopted in the Metropolitan houses, and elsewhere; where the system admits of two rooms, as a drawing-room and an ante-room, being practically thrown into one by removing or folding back the folding door—hence so called. In this form here illustrated there are two trussed or braced divisions, a lower and an upper (*a a* is the sill); strictly speaking there are three, as the lower is divided into two braced parts. The upper and lower divisions are separated by the beam or piece *c c*, carrying two posts *e e*, which run up in line with the lower posts *d d*. The lower braces butt against the side *a a* and the posts *d d*—the upper braces *g g* against *c c* and the posts *e e*. These are braced at head by the horizontal straining-piece *f*; this being the member to which the designation in partition work is strictly or more correctly applied—although it performs the same office in the other places we have referred to as here; the filling-in pieces are at *h*, *i i* the opening for the folding doors. In fig. 8, Plate III., we give an illustration of another adaptation of the double-framed partition—to a place where two side doors, one of which is shown at *k*, are required at the sides of the central folding

doors, void for which is at *j j*. In this there are four posts—two only being shown in the half-drawing—in addition to the two principal posts *a*, *b*, one of which is shown to the extreme right of the drawing. The braces, *e e*, of the lower division of partition butt against the posts *d d* and *f f*, at head and foot respectively. The braces or obliquely placed timbers in the upper division butt against the piece *a a* and the posts of which one is shown at *g*; *h* is the straining-piece, *e e* the filling-in pieces, *b b* the head, *a a* the sill of partition.

Principles of Partition Framing as applied in Timber House Construction.

The principle of the trussed or framed partition enters largely into the construction of houses constructed wholly of timber. Of houses of this class there are very many more examples to be met with in this country than many of our readers would be disposed at first mention of the subject to believe. Those of our readers who have seen much of the county of Essex will no doubt remember meeting with numerous examples of wooden structures not only adapted to farm building purposes, the examples of which are numerous, but to the farmhouses themselves, to cottages, and even to structures more pretentious than cottages in the way of internal accommodation. And other counties besides that of Essex can show a goodly number of wooden domestic structures. They are still more frequently met with on the Continent, where the art of timber working, both in its useful and ornamental features (see for the latter remarks and illustrations in the volume entitled "The Ornamental Designer in Wood, Stone, and Metal"), is carried to a much greater point of perfection than it is with us. In the United States of America, in Canada, and in our other colonies, timber construction is widely adapted to domestic and rural structures. In America "log" and "frame houses" were at one time almost universal; and although houses built of more durable and less combustible materials are not now, as formerly, so much the exception, still it may with some degree of safety be stated that wooden houses are the rule throughout the States. The "log house" is so called from the fact that the walls or inclosing sides of the house—or rather room, or at the most two rooms as a rule—are formed of the rough boles of trees, called there "logs." Those are not the same, however, as the "logs" we are accustomed to, which are "squared" at sides and ends. In the true log house the large timbers are very little altered from their original form as left when the trees out of which they are formed are cut down or felled. Sometimes, but not always, they are squared, and this only partially, at the upper and lower sides, so

as to admit of some kind of level "bearing surface" being obtained. But often they are laid together in the most even way their natural forms admit of, the spaces between being filled up, at least in the interior, with clay or mortar daubing to keep out the weather. These structures are only used in the interior and rural districts, being put up when the settler first "breaks ground," and kept up till his gathering means and greater prosperity afford him the opportunity to have the great ambition of a settler's life—a "frame house."

The frame or framed house is met with everywhere in town and

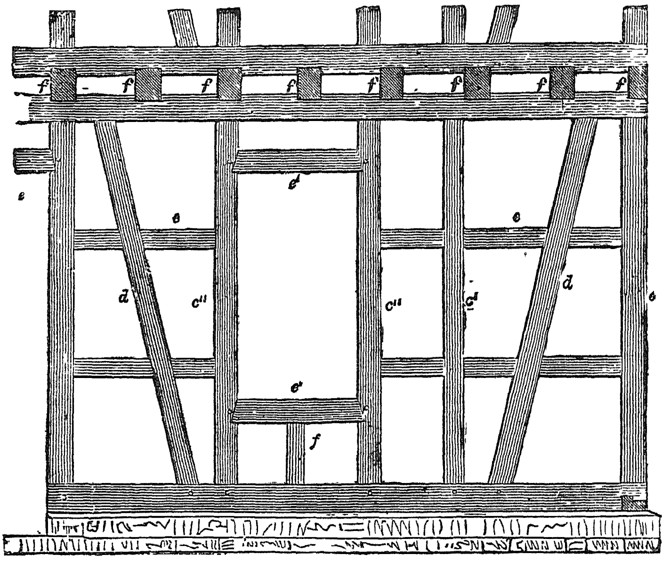

Fig. 89.

country throughout the States; and when large, houses of this class afford splendid examples of well designed and constructed timber framework. It is needless to say that, with their enormous tracts of finely-timbered country, the Americans are first-rate carpenters. Indeed, if we want to see what can be done with timber, we must pay a visit to that country. Some of the boldest—indeed, the very boldest—examples of what may be called timber architecture or engineering are to be met with in the United States. We have also named the Continental workers in timber as doing excellent work. The principal features of framed-house construction are well illus-

trated in the drawings in fig. 2, Plate XIII., the details of which the reader, who has followed thus far in our various illustrations and descriptions, should have no difficulty in understanding Plate XIV. gives an elevation with detailed drawings of a timber or framed house or cottage for colonists and emigrants.

Roof Framing.—General Statement of Peculiarities.

Still following what appears to be the natural sequence of timber framing, as exemplified in domestic and civil buildings, we come now to the subject of roofs, having described and illustrated the subjects of floors and partitions in preceding paragraphs.

The roofing or roof of a house is the part of the building which extends over its highest story, and shelters its interior from the weather. The roof comprises two distinct parts, which are first the covering and second the framing or framework of timber which carries or supports it. This covering or upper part of the roof is composed of materials suitably chosen and arranged to form an impervious surface. This covering is placed on filled or open-work floors, nailed upon sloping beams which are sustained by other vertical beams The combination of these different beams forms the framing which is that to which the term roof is generally—indeed, universally—applied. The framing determines the form of the roof, and presents, like it, outer surfaces plain, inclined, curved, or arched, the object being to facilitate the draining away of rain and snow, from which the roof protects the house.

The materials usually employed in the covering of roofs are slate, tile, thatch, zinc, copper, and lead. Slate is generally used—always for superior houses—and is of various sizes and qualities. Tiles are comparatively seldom used with us, but largely on the Continent. When used in this country, it is chiefly in cottages in rural districts. The "craze" for houses in the "Queen Anne style" so called—architects having apparently failed to found a style which would be representative of the "Victorian" era—has of late years created a demand for red tiles for roof covering, these being considered most appropriate for this revived style. Thatch is only used in the country, and we only speak of it to point out its danger in case of fire. It is on this account absolutely forbidden in the centre of towns by police regulations. Even in rural districts its use is fast dying out. Zinc has for some years been used with great success for the covering of buildings, but chiefly public and manufacturing, although we now see a considerable number of houses covered with this metal. Copper forms an excellent covering, but is rarely used on account of its high price. Lead has not only the disadvantage

of being expensive, but also of weighing enormously in proportion as the space or roof surface increases. It is rarely used, except in very special structures; in ordinary roof work it is confined chiefly to the "flashings" round chimney stalks, to make good or cover up

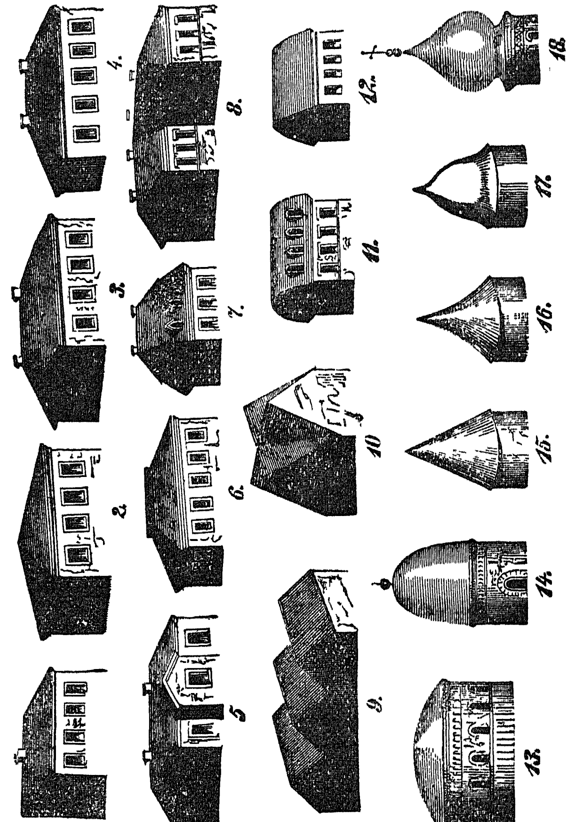

Fig. 90.

the joints or spaces left between the slates and the brick or stone work of the chimney stalks. Ridges are generally flashed with lead —often with ridge tiles—and lead is used also in ordinary roof work for the covering of flats, as at skylights and at bay or projecting window roofs.

Roofs assume throughout various countries an almost endless variety of forms, representative types of which are given in fig. 90, and explanations of which will be given when we come to give special descriptions of the constructive features of the different forms in general use, but of which those chiefly used may be here named. No. 1 is the "lean-to" roof; No. 5, the "gable-ended" or "span" roof; Nos. 2 and 4, the "hipped" roof; No. 6, the "pavilion" or "coach-house" roof; No. 7, the "Mansard" or "Continental" roof; No. 9, the "ridge and valley" or "multiple gabled" roof; No. 11, the "semicircular" or "barrel" roof; No 12, the "saddle" or "curved" roof; No. 13, the "dome" or "hemispherical" roof; No. 15, the "conical" roof; No. 17, the "ogee" roof; and No. 18, the Moresque" or "Arabian" roof.

Roofs, by reason of their different forms, may be divided into two principal kinds, the one comprising roofs formed of planes or flat surfaces, as in Nos. to 10, fig. 90; the other, those where surfaces are curved or arched, as in Nos. 11, 12, 13, 14. The height suitable for a roof considering its base should be determined principally according to the kind of covering which it is intended to support. In countries where rains are frequent and snowfalls heavy, the height requires to be greater than in southern countries, in order to give to their roof a greater slope.

The slope, the nature, and the weight of the materials which form the covering of a roof, make a considerable difference in the expense of building it In the case of a terrace or flat roof, for example, the surface of a covering is equal to that of the space to be covered. A roof of a third of slope has a fifth more length than its base; and if this slope is of 45° the surface is equal in development to once that of the base *plus* the two-fifths of this base. In short, the expense increases more and more according to the slope of the roof, to such a degree that, with an angle of 60°, the section, if an equilateral triangle, gives an area double that of its projection. The cube (cubic weight) of the wood of the framework increases also by reason of the elevation of the roof through the necessity which it entails of giving more strength to the joints and to the different pieces which form them, in order that they may resist the action of the wind. With regard to the materials which cover the roofs it is to be observed that they differ essentially in weight. Thus, if a square yard of covering in zinc weigh say 15 lb., in slate it will weigh 45 lb. and in tiles 225 lb. Zinc is, then, two and a-half times lighter than slate, and fourteen times lighter than tiles. It is considerably lighter than copper or lead. We must also add that of snow, a layer of which is equivalent to a surface of water having a thickness about

$\frac{1}{20}$th that of the snow (and a gallon of water weighs $6\frac{1}{2}$ lb.). The framework of a roof intended to support these different materials should, however, present parts with equal powers of resistance; consequently the expense increases in proportion to the weight of the material forming the covering.

From the preceding remarks we can easily calculate the economy there is in general in giving to the roofs the least possible height, both on account of the frame and of the surface to be covered. However, a light covering capable of being used under a very slight slope may often use up as much wood as another heavier one requiring a very decided slope, because the less the slope of the wood the better it resists the weight it has to bear. We must not omit to mention that certain forms of curved roofs afford a considerable relief to the supporting walls, which then have less weight to support. It results from a great number of measurements that in a building of a medium width the cube of the timber or wood of the roof may be approximately estimated by the square yard of space: thus, suppose a roof covered with slate with a slope of 60° takes 105 cubic feet, it will take 90 for a slate roof with a slope of 45°, 58 to 68 for a roof covered with hollow tiles laid without mortar at an angle from 1° to 21°, and 67 to 72 in hollow tiles plastered, supported on wood boards at the above angle. We have not included in this estimate the cubic feet of timber of the tie beams of the framework of the tiles, because these pieces enter more particularly into the composition of the floors of attics or rooms immediately below the roof, where they serve as beams or joists; and in this case their dimensions are very variable according to the weight which the floors have to support and the points of support which are beneath them, such as those obtained from partitions in timber or brickwork. In a roof of 45° the height is the half of the base, and the angle at the summit is a right angle; but this arrangement for ordinary work is not to be recommended, still less those the height of which is still greater. There are, of course, exceptions to this, where the roof is purposely designed to be very high, in keeping with certain styles. In rainy countries the height of slate-covered roofs is generally made about a third of the width, because slates have the disadvantage not only of absorbing the water, but also, on account of their smooth surface, that of causing it to rise again, which as we know is the effect of capillary attraction. For hollow tiles we can diminish the height of the roof to a fourth of the width, because each row of hollow tiles forms a species of gutter, and thus gives to the water which it collects more force in flowing away. As to the metallic coverings, such as zinc or copper,

they are not limited to any slope, except what is indispensable for the flowing away of the water—as, for example, in the case of a terrace or flat roof. Too high a roof generally disfigures a domestic building, and as a dwelling it makes a bad shelter—too warm in summer, too cold and damp in winter. But as those of our readers know who are acquainted with Continental architecture, the high-pitched roofs give a fine effect to many buildings, even to domestic structures.

The Classes or Varieties of Roofs.

We have said that roofs are divided into two great classes: first, those in which their outer or upper surfaces are composed of planes or flat surfaces—those generally placed at varying angles or slopes to the horizon, or in relation to the vertical walls of the buildings; and second, those of which the upper or external surfaces are in lines of varying curvature. The first of those classes comprises the forms of roofs which are in most general use—the curved form being rarely used for domestic or ordinary structures. This, the principal division or class of roofs, is again divided into two sub-classes. The first of those embraces the different constructions employed in the simplest of all roof framework—in which the distinguishing feature is that the slope or inclination of the roof is to one side only of the building—the front and back walls of which are of unequal height, as in No. 1, fig. 90. This form of roof is called the "lean-to" or the "pent-house" roof. In the second class the slopes or inclined surfaces are at equal angles on both sides of a central line—this line being in the centre of the building, or midway between the front and back walls—both of which are of equal height. This kind of roof, by far the most common, is termed a "span roof" or "trussed roof"; the latter name being derived from a constructional peculiarity in the framework, which will in due course be further, although it has already been partially, explained. The span roof is illustrated in its most common form in No. 5, fig. 90; but all the figures from No. 2 to 10 inclusive are different arrangements of span roofs also, although known by different names, hereafter to be noticed.

The "Lean-to," "Shed," or "Pent" Roof.

Taking now the first of those classes, we shall give illustrations of different forms of "lean-to" or "pent-house," often also called "shed roofs." Of these the simplest is illustrated in fig. 3, Plate X., in which *a a* is the back or the higher, *b b* the front or lower wall; the distance *c c* being what is called the "span" of the roof; spars or rafters, *c*, *d*, stretch across from wall to wall, resting on or built

into the walls at upper and lower ends. These spars are placed at intervals on the walls corresponding in distance to the strength or "scantling" (*i.e.* the measurement of its depth or breadth and thickness) and the width of "span" *c c*. These intervals may be from three to six feet On the spars boards are laid at right angles to the lines of their length, or parallel to the walls—and on these boards are placed the roof-covering material, as zinc, slates or roof-felting. If tiles be used, they are supported by light spars, nailed at intervals corresponding to the length of the tiles to the upper surface of the rafters *d*, *e*, fig. 3, Plate X., these light spars running parallel to the walls In fig. 4, Plate X., we give another form of "lean-to" roof, in which a new member or piece is added—namely, the "tie beam" *a a*, the rafter *b b* being notched into this and projecting beyond it at lower end, as at *c*. In fig. 5, Plate X., we give another form, in which a third member appears: this is a "strut" or "brace," *d*. This butts partly on the "tie beam" *b b*, and partly on an upright piece let into the wall, or merely against the wall *c c*; and at the other end is let into the lower face of the rafter *b b*. In fig. 6, Plate X., we give one method of securing the upper end of the rafter, *b*, of a lean-to roof to the "wall plate," *c*, which is a piece of timber built into and running along the whole length of the wall of the building or shed to be roofed over. The foot or lower end of the rafter, *e*, is notched to a corresponding wall plate, *f*, fixed in the front wall, *g* shows the gutter, and on the upper side of the rafter two of the planks or boards to support or carry the roof covering, as slates, are shown.

Span or Gable-ended Roof.

We now take up the illustration of roofs of the second class, or "span roofs," the peculiarity of which we have already described. The simplest form of roof of this class is shown in fig. 1, Plate I., the rafters *a*, *b*, resting at the feet on the walls *c*, *d*, and butting against each other at their upper ends, as at *e*. This arrangement is only suitable for small spans—if indeed for those, as the tendency of the weight of the roof to push out the walls laterally is in no way counteracted. To obviate this great defect a horizontal tie called a "collar" or a "collar beam," as at *a* in fig. 2, is used. In some cases two collar beams or ties are used, as in fig. 3, Plate I. In this arrangement "purlins," as *e*, *d*, are added at the lower collar: the use of these members will be described in connection with fig. 9, Plate I. The method of giving a horizontal tie, such as the collar beams, as in figs. 2 and 3, Plate I., above the top line of the walls, does not give so sound a construction as where the tie is

placed at the level of top of the walls, as at *a* in fig. 5. In this still simple form of "span roof," the rafters butting at point or apex *d* of the roof, are supported by "braces" or "struts" (see *e* and *f*, figs. 9 and 10, Plate I., *b b*), butting at the lower ends against the "straining sill" *c*, laid on upper face of tie beam *a* Or the feet of the braces may be notched into the upper face of the beam, dispensing with the sill or cill *c d*, fig. 10, Plate I. The scale to which figs. 1, 2, 3, and 5, Plate I., are drawn, is given in figure.

Trusses.—The King-Post Truss.

Figs. 1, 2, 3, and 4, Plate I., are but approximations to the true form of which a "truss" with all its members is the distinguishing feature. The most simple form of truss is that known as the "king-post truss," illustrated in fig. 9, Plate I., in side elevation or end elevation—that is, as it is placed in its position standing vertically on the walls *b b′*, the space between which the truss "spans" or stretches over. Those "trusses" drawn to the scale in fig. 10, Plate I., are placed along the wall at intervals, as shown at *a a*, in edge view or side elevation, and are connected together and supported by the timbers termed the "wall plates," purlins, and ridge poles, presently to be described.

The elevation in fig. 9, Plate I., represents a "truss," the principal parts of which are: The tie beam *a a*, which supports the whole of the truss; this tie beam rests here on the upper part of the walls. It generally supports the floor of the attic, if there is one below the roof. The "principal rafters," *c*, *c*, oblique pieces which serve to support the roof, and which are joined to the "tie beam" *a a* with tenon and mortise, in the manner described in preceding illustrations under the head of "Joints." These pieces, instead of uniting simply at the angle which they form at the apex or summit of the truss, are joined to the opposite surfaces of a vertical piece *d f*, called a "king post," at a point near *d*. The "king post" *d f* is, as we have just said, a vertical piece to which are joined the principal rafters with tenon and mortise, and which is joined to the tie beam in like manner. This joint is sometimes kept together by an iron strap (see Joints, *ante*, and Straps later on). These four pieces—tie beam *a a*, king post *d f*, principal rafters *c c*—suffice to form a "truss"; and as the whole represents two triangles, the figure or framework will be the most rigid which can be obtained, and capable of resisting all the pressures to which it may be subjected, without the timbers being displaced, the triangle being the form of greatest rigidity in which the materials can be placed. A quadrilateral

figure or form or timber is, on the contrary, so weak, so little able to resist pressures, that if the timbers were at all heavy its own weight would, so to say, dismember it or cause it to fall. If not, a very trifling pressure, as weights resting on the upper part, would disarrange the framework and cause it to collapse. A frame in the form of a triangle, as the truss in fig. 9, Plate I., would, even if made of very slight timbers and thus weak in its individual members, as a whole support a very great pressure or weight comparatively pressing downwards at the point *k*, the pressure being by the very form distributed so that it would be transferred to the walls and tie beam. The pupil will derive some useful practical hints as to framing by constructing simple frames of different forms. He should also study the paragraphs and illustrations in a succeeding chapter on the principles of framing and framework

Although the four members—the "tie beam" *a a*, fig. 9, Plate I, the "king post" *d f*, and the two "principal rafters," *c c*—form a triangle, or what is called a "truss," to complete it as used in practice the "king-post truss" has another member or piece. This is the strut; the "struts" or "braces," as *e*, *e*, oblique pieces resting on their lower ends at the foot of king post, being mortised into same (see Joints, *ante*), and notched at their upper end to the lower side of the principal rafters The trusses thus completed are set up at the proper intervals along the walls, as shown in fig. 9, Plate I, and are kept apart first by the tie beam being secured to the "wall plates" *b b*—ends shown in cross section—which are built into the walls along their whole length.

The second mode of connecting and securing the trusses, as *a a a*, is by the use of what are called "purlins," shown in cross section at *g g* in fig. 9, Plate I. These purlins are carried by the principal rafters *c c*, and are secured to them by one or other of the methods illustrated in the chapters on Joints (*ante*). They run parallel to the walls, or at right angles to the trusses, and are shown in side elevation at *b b* in fig. 2, Plate III These purlins have another office to perform. The spaces or intervals between the trusses as placed on the walls as at *a a a*, fig. 2, Plate III., are obviously too wide to be covered over with the boarding on which the slates are carried. This boarding is in the king-post truss carried by what are called "common rafters," which are much lighter—that is, of less scantling—than the principal rafters. These common rafters are shown in end elevation of truss fig. 1 at *h h*, and in side elevation in fig. 2 at *c c c*. They butt against each other simply at the ends, as in fig. 1, Plate I, in the simpler constructions; but in those of a better class butt against and are secured to what is called a

"ridge pole" or "plate," *l* in fig. 10, and at their lower ends are notched to "pole plates," as *i i* in fig 9, Plate I. Both the ridge pole or plate *l*, fig. 10, and pole plate *i i* in fig. 9 are parallel to the purlins *g g* and wall plates *b b*.

In ordinary domestic structures the end walls of the building are carried up to the same height as the ridge pole *k*, fig. 9, Plate I., and form the same triangle as that of the truss; in this form the roof surface slopes only on two sides, as shown in No. 5, fig. 90, p. 47. Those end and angular-shaped walls at upper part may be looked upon as acting as trusses, the trusses proper of timber being spaced out between the two walls. Those angularly terminated end walls are termed "gables," and the roof itself a gable or "gabled roof." Sometimes, when the attic or garret is to be separated into two or several parts, the inner parallel walls are carried up in the same way to the gables. When these walls are near enough they completely take the place of trusses, and support directly the purlins, as *g g*, and common rafters *h h*, fig. 9, Plate I.

Hip Roofs.

But it happens also in certain constructions that there are nc gables or end walls carried up; then the roof is sloped on four sides, and the sloped surface of the narrowest side takes the form of a triangle, as we see to the left hand of diagram No. 4, fig. 90, p. 47. This form of roof is called a "hip roof"; the angles formed by the meeting of the hip roof and the sides are called "hips," and the rafters "hip rafters," etc. The hips in large roofs are formed by half-trusses, in everything similar to those which we have already described The principal rafters of the trusses of hip roofs are joined to the king post of the truss of the sides or largest part of the roof, with a tie beam resting on one side upon the wall and on the other joining to the tie beam of the truss. The construction of gabled and hip roofs on the "king-post truss" principle now explained will be further and practically illustrated by figs. 1 and 2, Plate XV., and of which the first-named figure will give additional illustrations of parts described in former chapters, such as floors, etc., and various details of joinery, and masonry and brickwork, this being a longitudinal section of one of the houses illustrated in connection with the volume entitled "The Domestic House Planner." This section illustrates a roof of two parts of the house, one of which is at right angles to the other. Thus A A in the drawing is the side elevation of the roof of that part of the house which runs from left to right, C C being the "hip"; B B is the elevation of that part of the roof running at right angles to A A and approaching the spectator. This

roof B B is a "gabled" one, D being the elevation of the furthest-off gable. In this there are no timber trusses, as this part of the house is short; the distance between the gables is sufficient to give strength to support the roof timbers, the common rafters, as B B, being carried by the purlins shown in cross section at E E, those again being carried by the gables, as also the ridge pole. Fig 2, Plate XV., is the plan of roof of a house nearly square in plan, the drawing showing to the right one half of the plan of outer or finished or slated surface A A A, the other half to the right, showing the disposition of the timbers B B, C C being the "hip." The roof in this case is finished with a flat part at the summit, as shown.

We have now described the various parts of a king-post truss or timber framework of a roof,—those which form, so to speak, its skeleton. It only remains now to put up a timber flooring or boarding over the whole, in order that it may be covered with slate or zinc. The purlins and the ridge form the beams of this inclined floor, it will suffice then to add to it supports to which the covering boards may be fastened.

The supports in this case take the name of common rafters, as *c*, *c*, fig. 9, Plate I.; these pieces are placed on the purlins *g*, *g*, in the direction of the slope of the roof, and are supported by their upper extremity, cut with feather edge to the ridge pole, to which they are fastened with nails or pegs; the rafters are generally simply nailed; they are placed 18 to 24 in apart.

The feet of the principal rafters are supported by the wall, but not directly; they rest on a horizontal piece called the wall plate, to which they are nailed. The wall plate, or platform, is a flat and wide piece which rests on the top of the walls and is secured or jointed (see Joints) on the ends of the tie beams. The wall plates receive, as we have just said, the foot of the rafters.

When the walls are very wide, or the truss so made that the rafters or common rafters do not cover them completely—that is, project beyond—small pieces are added more sloped than the rafters, which are supported on one side by these latter, and their under sides rest on a small wall plate. This is illustrated in the form of high-pitched Continental roof in fig. 2, Plate XII.

It often happens that, to gain more space in the garrets, the walls are raised above the tie beams, as in this last figure. Then the principal rafters, instead of resting directly on the tie beam, are supported by a horizontal piece, as shown in the diagram.

The Queen-Post Truss.

We now proceed to illustrate and describe other forms of roof

trusses, of which the first we notice is that known as the "queen post"

This truss, illustrated in diagram (fig. 10, Plate I.), is used in structures of greater size than those in which the king-post truss is employed, in which the "span" or void between the walls to be bridged over, so to say, is wide; or for situations in which a clear space is required in the centre of the attic or garret room above the highest story or within the inclosed space of roof. This free central space is obtained, as the reader will see, by dispensing with the central king post as used in the truss in diagram fig. 9, Plate I., and using two pieces or members which are modifications in form of the king post. Those pieces are termed "queen posts," are placed the distance apart required to give the clear central space above alluded to, and are shown in position in the diagram in fig. 10, Plate I., at *a* and *b*. Those are kept apart at top by a horizontal piece marked *c*, called the "straining beam," and at the lower part or feet by a similar but thinner part *d*, called the "straining sill." The "queen posts" *a* and *b* are, like the king post in diagram fig. 9, Plate I., jointed or secured to the "tie beam" *e*, which is carried by "wall plates." The principal rafters, as *g*, rest at their feet on the tie beam *e*, and butt at their upper ends on the heads of the queen posts, as *b*. "Braces" or "struts," as *f*, support the principal rafters *g*, and are connected at their lower end to the feet of the queen posts. The "purlins," *h*, are carried by the principal rafters, and carry the "common rafters" *i*; the lower ends of which rest on the "pole plates," as *k*, and the upper ends on the "ridge pole" *l*. That in fig. 1, Plate III., illustrates a queen-post truss for a wider span than that of fig. 10, Plate I. (the scale for which is below the figure). In this truss (fig. 1, Plate III.) a second set of "queen posts," *a a*, and struts or braces, *b b*, is added; in trusses of this kind for very wide spans there are three sets of queen posts, with their braces. The methods in use for effecting the junction of the various parts both of "king-post" and "queen-post" trusses will be found illustrated and described in the appropriate place in preceding paragraphs on the joints used in carpentry.

The Mansard, or Curb Roof.

We have now passed in review in succession all the pieces which form the framework of a roof; we have pointed out the difference between the essential pieces and those which are only needed to strengthen the former. It is for the carpenter to judge if he should use the latter, according to the dimensions of the timber he has at command and the nature of the building he has to roof over.

The trusses—"king-post" and "queen post"—which we have given in figs. 9 and 10, Plate I., and fig. 1, Plate III., as we have already said, are those generally used in ordinary or domestic buildings. We can, however, according to circumstances, modify the proportions of the height of the truss without changing its arrangements. We could, for example, make the height equal to the base while keeping the same arrangement of the pieces, these are modifications which the intelligent reader will easily make. It is sufficient for us to have pointed out the composition of these trusses and the manner in which the pieces should be arranged.

We will not at present treat of the different forms of truss which are still in use, but which are inferior to those we have described both as regards simplicity and economy. There is, however, one arrangement of roof truss, which we illustrate. The Continental architect "Mansard," who was the inventor of it, gave it the name by which it is best known abroad; that of "curb" roof being very generally adopted with us. Its use is extending amongst us, coincident with the more extended adoption of that style of architecture, especially in public buildings, in which the high-pitched roof, so well known to Continental travellers, is a distinguishing feature. Examples of this form of truss, or modifications of it, are therefore to be met with more frequently amongst us than formerly, these at one time being confined chiefly to towns of the Continent.

This form of truss is illustrated in the second diagram in fig. 1, and the half to the left in Plate XVI. The outline of the form is obtained by the following. From the centre of the "tie beam," and with a radius equal to the half of the width of the building, describe a semicircle; divide this semicircle into ten equal parts, and carry two parts from the base to the first projecting point to the left, and three from this point to the summit at the middle of the curve; join the projecting point with the summit and with the base, and two lines which determine the form of the roof are obtained. Two methods of arranging the roof truss are shown in the diagram —one on each side of centre line *a b*.

In some cases the semicircle is divided into four parts, and then the projecting point is at equal distances from the base and the summit. The projecting point determines the height of the upper tie beam, which is supported by vertical posts in the truss illustrated to the right of the centre line *a b*, second drawing in fig. 1, Plate XVI. The braces or struts are joined to the main tie beam and to the upper tie beam; they are supported by braces, such as shown by the dotted line to the left of the centre line *a b*; these pieces, or others acting in the same way, are indispensable to prevent the

angular frame formed by the braces, and the upper tie beam losing its proper shape. This bracing up of the lower framing may be done in other ways. Thus, in the truss shown in half elevation to the left of centre line *a b* (see group of drawings in fig. 1, Plate XVI., the strut or brace shown by dotted lines may be used, this butting at the foot against foot of vertical post, and at upper end partly against lower side of tie beam and partly against the strut. The bracing or strutting will be more complete if the extra strut be given. This Mansard truss gives a wide space in the centre of the roof—forming a good attic. In the truss, half of which is shown to the right of centre line *a b*, the bracing up of the lower frame is effected by the disposition of the timbers which give a partition with a door at each side.

Above the upper tie beam come the principal rafters, which are joined to the king post in the same manner as for a king-post truss. The principal rafters may besides be supported by braces, as shown. The ridge and the purlins are placed in the way that we have already pointed out. Mansard roofs are terminated like simple roofs, either by gable ends or by hip roofs; they are also made with bays, and are, as we see, composed of nearly the same pieces of wood. When the Mansard roof forms a hip roof, a sloping part in the floor of the upper story or attic is made, in the same way as in roofs with king and queen post trusses—the height of the attic room gradually decreasing towards the eaves of the hip. At the time that Mansard invented the roof to which he gave his name, it was thought indispensable on the Continent to give a great height to the roofing of nearly all buildings. Many specimens of this are met with in the roofs of old buildings. Mansard was the first to think of utilising the immense space formed under those high roofs, by the truss he invented. Thus the part below the upper tie beam is generally divided into rooms, and the tie beam then serves to support the joists of the ceilings of those rooms. These rooms are called Mansards. This system of trussing was certainly a great improvement upon the old forms, of which we give illustrations in fig. 7, Plate X., and figs. 2 and 3, Plate XII. High-pitched roofs form a feature of Gothic architecture, and we give in figs. 1, 2, and 3, Plate IV., forms of trusses for Gothic roofs. Fig. 1 shows a truss with an attic in the space having a coved or sloping ceiling—the sides sloping being formed by the struts or braces *a b*. The sides of this attic room do not go in or slope away to nothing in the corners *c c*, but are made vertical by the vertical pieces *d e*, which are called technically "ashlets." The principal rafters are continued upwards, and the upper part finished precisely like a king-post truss—with a

false or extra tie beam. The common rafters and purlins may be added, as shown in the high-pitched Gothic truss, in fig. 3, Plate IV., which gives, as shown, an open roof with coved or sloping ceiling. Another form of Gothic truss with curved or semicircular ceiling is shown in fig. 2, Plate IV. In this the curved "ribs" *a a*, the under side of which form the semicircular ceiling, are supported at feet by projecting horizontal pieces, *b*, called "hammer beams"—these supported by braces or struts, *c*, resting on stone "corbels," *d*, built into the walls. The faces of the struts, *c*, and the ends of the corbels, *d*, are generally curved to present a moulded outline. The forms of trusses, as in figs 2 and 3, Plate IV., are adapted for large rooms—as schoolrooms. In fig. 7, Plate XVI., group to the left, we give part elevation of a high-pitched roof obtained by "cambering" or lifting up the tie beams, securing them to the king post by wrought or malleable iron straps. The whole strength of this roof truss rests in the integrity or strength of the iron straps. A truss for a many-sided (as a hexagonal) roof may be made on this principle—the foot of the king post in fig. 7 having as many sides as there are to be sides to the roof or in the building which it covers. The number of the tie beams—and of struts if these latter be used—is of course the same. Drawing No. 6, in Plate XVI. (group to the left of fig 1), shows part of the plan of a hexagonal or six-sided truss and building—the roof having at its upper part a lantern or skylight, the outline of which is six-sided, as shown in the drawing, and the "lights" or "sheets" of which are placed in the spaces between the rafters.

Parts of Roofs—Roof Openings.

Openings have to be made in the roofs both for the passage of chimneys and also to let in the light to attics. These openings always necessitate the interruption of several of the common rafters, which are sustained by transverse pieces of wood parallel to the purlins—those straining pieces which are joined to the uninterrupted rafters nearly in the same way as the binding joists which support the joists are joined to the beams of floors.

When the opening made in a roof is intended to let in the light, it may be closed by a glazed window skylight sash, which is raised or lowered like a shutter by turning on its upper horizontal side; but when the opening is to be made in such a way that the window placed vertically in the roof may be seen from the outside of the building, it is covered by a small timber-work construction called a "dormer-window," formed of two triangular parts or partitions, which are its sides, joined to the lateral rafters of the opening.

The sides of a "dormer window" support its roof. The "dormer window" is finished to the front by a fixed sash, forming a window to the front of the building, as shown in drawing No. 4 in Plate XVI. Group to the left in fig. 1 is side elevation of one of the sides of the "dormer window" in No. 5. This is composed of two vertical uprights, one of which is at *g*, joined to the two rafters, one of which is at *a*, by a cross-beam, *h*, parallel to the ridge; of two horizontal pieces, as *d*, supported by the cross-pieces, joined to the rafters on each side. These two pieces, as well as the cross-beam *b*, serve as a platform for the small roof to the "dormer window," the sides of which form a species of hip roof, *h* representing the hip rafters. The construction of these dormer windows presents, as we see, no difficulty. In roofs composed of flat surfaces they present the appearance of a small roof penetrating the front of a larger. We can modify in different ways the form and the composition of the roof of a dormer window, it is sufficient for us to have described one which it will be easy to modify according to particular circumstances. The openings meant to give an outlet to the chimneys present the same appearance as the square openings made for the building of the dormer windows.

Combined Timber and Iron Roofs.

Before proceeding to give illustrations of other departments of carpentry work, we have to describe forms of roof trusses in which timber is combined with iron—a species of construction largely adopted in this class of work. These forms, with the details of iron work, such as straps, tie rods, rafter boxes, etc., will together make a department of our paper of much practical interest to the pupil in carpentry work. We precede these examples of combined work by forms of trusses other than those given in the preceding paragraphs, in which the features of king-post and queen-post trusses are found more or less modified. In drawing No. 1, fig. 1, Plate XVI., we give a modification of the queen-post truss, as in fig 1, Plate III., which gives a flat or terraced part, as *a*, to the roof surface at the summit. In fig. 2, Plate XVI., drawing No. 4, we give elevation of a queen-post truss, with three sets of queen posts and two braces; in this truss a third brace is sometimes inserted in the last triangle to the right and left extremities. Drawing in No. 3, same figure, is modification of the queen-post truss in which the central king post in upper part is continued downwards and joined to the tie beam. Drawing No. 5 is a design for a truss on the queen-post principle designed to support the framework for a tower on its central part. Drawing No. 6 is a truss giving a rising or coved

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ceiling under, and No. 7 is a truss on the same principle as that in No. 3, but without the collar or straining beam, as *a* in this last-named drawing.

In drawing No. 15, fig. 1, Plate XVII., we give elevation, and in No. 16, plan (both drawn to the scale in No. 17) of a conical roof circular in plan, as in No. 15, fig. 90, *ante*. In fig. 1, Plate XVII., *a a* is the tie beam for supporting the central shaft of the machinery in the building for which the roof truss is designed. In No. 16, *a a a a* is the circular "wall plate" in which the feet of the principal rafters rest; the parts *b*, *b*, *b*, *b*, correspond to the "purlins" similarly lettered in No. 15; *c*, *c*, *c*, *c*, the "principals" or "principal rafters"; *d*, *d*, the filling-in or straining pieces. In fig. 90, p. 47, and in figs. 1, 2, and 3, Plate XVIII., we give drawings of trusses for roofs. which illustrate various methods of Continental construction in timber.

Various Forms of Roofs.—Polygonal Roofs.

We give here a few remarks on polygonal roofs, which are often classed under the general term of pavilion roofs. A pavilion roof proper, however, has for its general features four sloping surfaces, as No. 6, fig. 90, p. 116, two of those being at the front and back or longest sides of the building, and two formed by the hips at the end, as shown; but the special feature of the pavilion roof is this,—that those four sloping sides do not go up to a point, as shown in the diagram, but stop short at a certain part of their height, and the roof is finished with a flat surface, the sides of which, parallel to the back and front walls, are the longest; the ends parallel to the end walls being the shortest. The flat thus formed is of course level, or with its surface parallel to the floors of the house or to the ground level-line. Considered in the sense of their having many sides, pavilion roofs may be defined as above—namely, polygonal. They are raised upon buildings the plan of which is square, or formed by some regular or irregular polygon; they are composed of as many triangular slopes as the polygon has sides or angles, so that they form together a pyramid; they are distinguished from one another by adding to each of them a qualification derived from the polygon which serves as a base for it. Thus, we say of a pavilion that it is a pentagonal, hexagonal, square, etc., according as it has four, five or six sides. The height of pavilions is very variable; but when the proportions that we have pointed out for ordinary roofs are deviated from, it is because a more ornamental design is in view.

If what we have already said upon roofs has been understood, the construction of pavilion or polygonal roofs will not present any diffi-

culty. Instead of having two hip roofs, two lateral or side slopes, we shall have four, five, six, or eight hipped surfaces. The hips will be formed of half-trusses, the principal rafter of which is joined to a king post common to each of them; these half-trusses taken two by two form actual ribs when the base is a regular polygon composed of an equal number of sides. If the polygon is irregular, or the number of sides unequal, the construction will not present any difficulty, although the half-trusses are of different plans.

When the dimensions of the polygon are not very great, we simplify the construction very much, and instead of half-trusses we use merely hips joined to the king post and the platform. These hips are joined together by purlins, and the rafters are placed exactly as in the hip-roofs of simple roofs.

It is evident that the king post should always have a number of faces double the number of sides of which is formed the polygon which serves as a base to the roof—except, however, where there are no principal rafters, the only case in which it takes absolutely the form of the polygon. These short observations will suffice to explain the manner of building pavilions, and in the foregoing paragraphs will be found details relative to the hip-roofs of simple roofs which apply exactly to the roofs of which we are now treating.

When the base of the pavilion, instead of being a polygon, becomes a curve of any kind, the roof takes the form of a cone. We shall examine an example where the base is a circle; and what we shall say here will apply easily to those instances where another curve is adopted.

These roofs are composed at first of the principal rafters, which are joined at the top to a king post, placed in the centre of the truss, and at the bottom to a platform or circular wall plate. The wall plate is sometimes double, in which case these two wall plates are joined together by cross-pieces. Small vertical pieces or ashlets placed on the second wall plate serve to strengthen the feet of the rafters. The rafters are strengthened by what may be called secondary means by tie beams which are joined to the king post.

The number of rafters is never more than eight or less than four. It is obvious that as these rafters are placed further apart in proportion to their distance from the summit, it is necessary to fill the void which they leave; for that purpose, and at the height where the distance between the rafters becomes equal to fourteen or eighteen inches, they are joined by cross-pieces which serve to fasten the upper end of shorter or common rafters between the principals. If the roofs have much height, we may be obliged to place several rows of cross-pieces at successive heights. In general they should be made

when the distance between the rafters is more than fifteen to eighteen inches.

The wall plates and the cross-pieces should always take the curve of the part of the roof upon which they are supported; in the present instance they have the form of a circular arch. The different pieces are joined by tenon and mortise. The construction of these cross-pieces demands particular care, because their outer surface should be conical, and should correspond exactly with the form of the roof. When the base of the cone is not in the form of a circle, the simplest method of constructing the wall plates and cross-pieces is to raise the curve on the plan. drawn in full, with a template, which is then applied to the upper and under faces of the pieces; we thus obtain as exactly as possible the curve that they should have.

The joints of the rafters and other parts are made in the same way as in ordinary roofs. In some buildings the roof forms only part of a cone; that, however, does not modify the rules that we have just laid down: a section of a cone is made in the same way as a whole cone.

Roofs with Curved Surfaces.

We now come to the forms of roof trusses of which the outer lines give curved surfaces. The variety of curved roofs is considerable; they are curved either on the inside or the outside, or on both sides at once. The simplest are the cylindrical roofs which are necessarily used in buildings the plans of which are terminated by perimeters composed of straight sides. Groined vaults and cloistered vaults are used in certain cases, either to be lined with joiner-work, or covered with lathing coated over. Gothic arches are constructed sometimes of timber-work; they form merely a modification of the groined vaults (see the volume entitled "The Building and Machine Draughtsman" for methods of laying out groins, finding the surfaces of cylindric roofs and domes). Roofs may be spherical, either on the outside or the inside. In the first instance they come under the category of domes; in the second the spherical form is generally only an arrangement intended to receive a lining which gives to the wall the appearance of the intrados of an arch; lastly, the spherical form may be apparent at once in the inside as well as the outside. Ellipsoidal roofs are used in the same circumstances as spherical roofs, either to present on the outside their forms surbased or raised, or to give to the interior the appearance of an ellipsoidal arch. In the first instance they are constructed like domes; in the second, like spherical roofs.

The constructions in timber-work the object of which is to present the interior appearance of a spherical or spheroidal arch are frequently

covered by conical roofs—a form which agrees with that of the arch, and which admits of rising ribs radiating round the vertical axis common to the two surfaces; but when the timber-work which gives in the inside the appearance of an ellipsoidal arch is to be covered by a conical roof, there is sometimes some difficulty in joining the wood in such a way that the rafters may be sufficient for both surfaces.

It is obvious that the limits of this work will not permit us to give the details of these different constructions; our aim here is to show the parts of the art of the carpenter to which the workmen should every day have recourse, but we cannot enter into descriptions of work always difficult, not very often used, and for which there will be furnished detailed plans made out. We shall meet the scheme of our series of volumes if we give a brief description of two very ingenious methods used in the construction of curved roofs by substituting thin planks for, or rather making up or specially constructing beams for, the solid beams generally used.

Philibert Delorme contrived in 1561 the timber-work to which he has given his name. His aim was to construct at smaller expense than by means of the clumsy timber-work of his time; and his method is even now very useful when we have only planks or short pieces of wood at our disposal; but when long pieces can be easily procured, the kinds of timber-work in which these large pieces may be used to their full length will always be preferable. Philibert Delorme, however, never pretended that exclusive preference should be given to his system; he only proposed it for cases where the workman has at his disposal planks of little value, and small pieces of wood of whatever kind cut by the saw. This system has besides the advantage of keeping out the tie-beams, which have always a disagreeable effect, and which are prejudicial to the interior decoration of the covered spaces. By this method of construction we can give to the outline of the roof the semicircular, elliptic or pointed form; only it is then necessary to change the cutting of the planks according to the curve which we wish to have. We content ourselves with pointing out the details of construction for a semicircular arch; as to the rest it will be easy to deduce the modifications necessary in the particular cases which may present themselves.

The ribs or hemicycles *a*, fig. 1, Plate XVIII., which form the kind of roof of which we speak, are composed of curved planks fastened together with iron pins two by two, or three by three, in such a way that the end of the one corresponds with the middle of the other (fig. 3, Plate XVIII.). They are placed to the distance of sixty centimetres, at a metre one from the other, and are joined by

horizontal ties or purlins, *b*, fig. 4, Plate XVIII., passing through and fastened with a peg at *c* to the planks, to fasten them firmly. These ties, *b*, are connected with or bind together three contiguous rafters, and are placed like rounds of a ladder. As the joints formed by the junction of the planks two by two should always correspond to the middle of the plank adjacent to them—that is, "break joint" —it follows that the planks of the extremities are either equal to the half of the others, or equal to one and a half times their length. Philibert Delorme fixes this length at about one metre, and the thickness of the planks varies from three to four centimetres, according to their larger or smaller resting-point. But in any case we should try to make the length be contained an exact number of times in the curve to be made, if it is uniform; and we must also arrange the pieces in such a way that the fibres will cross equally, in order to give to the joints of the curve all the strength of which it is susceptible.

To obtain the curve of the planks we draw first on a smooth surface two concentric curves, *m o* and *l r*, fig. 3, Plate XVIII., in full size; these curves will be at a distance equal to the width of the planks, and according to the form wanted. We then mark the divisions *d d*, etc., through which we lead the dotted lines *d e*, etc., passing through the centre of the curve, and representing the perpendicular joints of the planks; this done, after having cut the latter all in rectangular parallelograms, we lay them upon the diagram in such a way that the interior angles *f* of each will touch the points which mark the divisions upon the curve *l r*, and the outer side will be tangent to the greates curve. We then cut away the parts which on either side go beyond the two curves, and which are: 1st, the small external triangles, as *g e i*; 2nd, the inner part, *d f r*; and 3rd, the two other small triangles, as *m o*, of the extremities, and resulting from the obliquity of the perpendicular joints with the large external and inner sides of the parallelograms.

To put up the ribs or rafters made with the planks, the draught of which we have just pointed out, we join them at the foot by means of grooves made in a platform *b*, fig. 1, Plate XVIII., placed in an offset upon the half of the walls. Then, to complete the outer surface of the roof, planks *v* (fig. 1, same Plate) in the form of small rafters are used, which are fixed by a small wall plate resting on the wall. As to the summit or apex *v*, to which is generally given the same form as to those of span roofs with two simple slopes, it is constructed according to the same principle as the curved part—that is to say, that we place in each bay a species of rafter also made of planks joined together, but straight, to bear like the others the lathing or

flooring intended to receive the covering, these rafters add much to the solidity of the work. If it be desired to make a ceiling in the interior of the roof, it is made as usual by means of laths nailed upon the inner surfaces of the ribs or rafters.

We add in the following table the dimensions of the planks for the curves composed of two thicknesses:—

Diameter of the Curve of Roof.	Width of the Planks.	Thickness of the Planks	Observations.
Metres.	Metres.	Metres.	The horizontal ties will have at least the thickness of the planks, and their width will be equal to four times their thickness. The keys will have the thickness of the planks, with a width double the thickness.
8·00	0·21	0 027	
12·00	0 28	0 040	
20·00	0·35	0 054	
30 00	0 35	0·070	
35 00	0 35	0·080	

The foregoing measurements are the directions of Philibert Delorme, the inventor of the system, the principle of which, we may add, is adapted to various kinds of timber construction.

Curved Roofs.

We now describe the method of forming curved roofs, as introduced by Colonel Emy, director of military engineering in France, and which has been employed with great success in several of our large structures.

The semicircles of Philibert Delorme are formed of planks placed end to end and flush; M. Emy's arches, on the contrary, are made of long and straight planks placed one upon the other like the leaves or sheets of a carriage-spring and curved in a semicircle on their flat side solely in virtue of their flexibility. The execution of this system of carpentry presents no difficulty beyond the capacity of an ordinary carpenter; the work is much easier than that of the semicircles made of planks on the Delormian system. In this there are only straight pieces. All the timber-work joints, into which these arches enter, are made by grooves without either tenon or mortise, as in all other kinds of carpentry.

The first work of this kind was the shed of Marac, near Bayonne, in France, constructed under the direction of M. Emy, illustrated in fig. 2, Plate XVIII. Each truss is composed of a semicircular arch, the ends resting vertically on the walls of two vertical or strengthen-

ing timbers, of two principal rafters, and of a small horizontal couple or collar tangent to the arch, and forming a tie-beam with short king-post. The whole is joined by braces perpendicular to the arch. The space between the floor and the arch is free. The arch is the principal piece of each truss, and upon its construction depend the strength and other advantages of this system of constructing roofs.

The braces are grooved, as well as the full faces of the arches, to one centimetre in depth, so that they form joints of two centimetres, which have the double object of keeping the arches fastened and of forming rests which prevent the slipping of the joints one over the others. Two pieces of 1 centimetre upon the two faces of the arch are grooved into the cheeks of the couples, to prevent splintering in the grooves of the joists.

The vertical strengthening timbers (fig. 5, Plate XVIII.), are 10 centimetres distant from the walls, but the first three braces of each side are prolonged beyond the vertical timbers, and penetrate 20 centimetres into recesses of 30 centimetres of depth (formed in the mason-work as shown in fig. 5, Plate XVIII). The object of this arrangement is to profit by the resistance of the walls, for the timber-work exercises no pressure upon them, it merely keeps the ribs in the vertical planes, and prevents any leaning in the direction of the length of the building.

Between the braces, which cannot be multiplied more without uselessly increasing the weight of the timber-work, iron straps and bolts are fixed, which press the leaves or planks of the arch together and prevent their slipping: the straps by making the surfaces adhere throughout their whole length, and the bolts by forming, besides their pressure, interior resting-points, because, being cylindrical and driven by blows of the sledge-hammer into holes bored very exactly, they leave no play in the leaves or planks which they cross perpendicularly. These bolts are about 18 millimetres in diameter, and are 80 centimetres apart, and experience proves that they do not cut the grain of the wood in an injurious manner.

We thus see that the braces, the straps and the bolts make the planks of an arch, so to speak, conjointly support one another, and effectually prevent their straightening. In an arch of 5 planks and 20 metres of opening, the development of the extrados is 60 centimetres more than that of the intrados; straightening is consequently impossible. Many experiments have proved that the tendency of arches to rise is very feeble; arches joined only with straps, without braces or bolts, left suddenly to themselves upon the block, have opened only 16 centimetres—that is to say, about 8 centimetres at each end: one man could without difficulty prevent this slight separa-

tion; thus the pressure proper of an arch, resulting from its force of elasticity, is almost *nil*.

In each truss three large triangles are formed outside the arch by the vertical strengthening pieces, the principal rafters, and the collar or tie beam. Their combination with the arch and the perpendicular braces composes a truss as invariable as permitted by the flexibility of the wood and the play of the joints; but in this system it is the inflexibility of the arches principally which produces the invariability of form, and entirely does away with the pressure of the truss on the top of the walls.

The leaves or planks which enter into the composition of an arch are 55 millimetres thick, 13 centimetres wide, and from 12 to 13 metres long. Two joists and a half, end to end, with square joints, are sufficient for the development of the arch. The joints are distributed in such a way that each of those of one row corresponds only to another joint of another row, and all are covered by perpendicular braces. All the pieces of the truss are 13 centimetres thick, like the arch and the principal rafters, except the vertical strengthening joists, the thickness of which has been carried to 20 centimetres. The trusses are placed at a distance of 3 metres from centre to centre, and are joined together by the ridge-pole, by the under-ridgeboard couple, by the purlins, and by free horizontal couples which embrace the pendent braces, fig. 2, Plate XVIII.

The resistance should not be the same in all parts of the arch, and we should strengthen the parts which in the joists correspond to the joints most liable to break. The numbers between the braces on the different parts of the arch, fig. 2, Plate XVIII., indicate the number of planks used in the construction of the arches of the shed.

The invention of arches with curved joists on their flat side has tended to great progress in the art of carpentry. This system, easy of execution, joins elegance to economy. Compared with the Delorme system, arches on the Emy system are very economical. They are much stronger, which admits of placing them 3 metres apart, whilst the hemicycles are only about 70 centimetres. However, the square of the arches is not double that of the hemicycles Thus, there is a saving of nearly half on the cube of wood. The timber-work of the shed, illustrated in fig. 2, Plate XVIII., necessitated the use of about 165 cubic metres of wood, whilst, for the same work done on the Delorme method, 233 cubic metres would have been required, and to construct a similar roof by the ordinary method 192 cubic metres would have been necessary. Exact calculations have shown that, for a portion of about 14 metres, the expense is the same for ordinary carpentry as for Emy's system. For the smallest buildings

there is economy in employing ordinary trusses, but for larger buildings the advantage is on the side of the Emy system. In many cases, especially when we wish to get rid of tie beams, these curved trusses may be used with advantage, even upon buildings of no great width.

Roof Trusses of Timber in Combination with Iron.

We now come to the illustration of roof trusses in combined work in which both timber and iron are used. Wrought iron is possessed of a much higher power of resisting a "tensile" strain—a strain tending to pull the fibres apart—than timber, which gives out its best capabilities when used to resist "compressile" strains, or to resist "compression." In combined work, therefore, we find that the parts which are under tensile strains, as tie rods, king-bolts and queen-bolts, are made of wrought iron; the parts subjected to compression, as rafters and braces or struts, are made of timber. If cast iron be used in combined work, it is employed chiefly for boxes to receive the ends of other parts (see fig. 1, Plate XVII., and Plate XIX.). Cast iron in wrought-iron roofs is also sometimes used to form the struts or braces, or those parts which are under compression. In the examples of combined work in roof construction in fig. 2, Plate XVII., in No. 1 the "collar" or "tie" *a* is of wrought iron, jointed to the cast-iron struts *b b*, in which the principal rafters lie, these being bolted to the rafters. In No. 2 the suspension rod or king-*bolt* *a* takes the place of the timber king-*post*. In No. 3 the rods *a* and *b* are of wrought iron. In No. 4 the struts or braces *a a* are placed in, or butt against, mortise holes in a cast-iron shoe *b*. Tie rods, *c c*, are passed through the lower ends of the rafters *d d*, and secured by bolts and nuts. The upper end of the rafters *d d* are "housed" in recesses made in the cast-iron rafter box *e*, while this carries at its lower part an eye, to which is jointed the upper end of the tie rod *f*, which passes through at its lower extremity the box *b*, and secures also the tie rod *c c*. In No. 5 the "straining" beam *a* is housed in the cast-iron shoes *b b*; queen-bolts, as *f*, *f*, pass at their lower extremities through cast-iron shoes *e e*, and also through the tie beam, and are screwed up by nuts as shown, the whole being thus united together; the "straining sill" lies between the cast-iron shoes *c c*. These also afford "housings" for the struts or braces, as shown. In No. 6 the king and queen bolts are of wrought iron, the tie beam, principals, common rafters, and purlins of timber, with cast-iron shoes. In drawings No. 1 to 14 inclusive, in fig. 1, Plate XVII., we illustrate the elevation and details of a combined wood and iron truss on the queen-post principle.

In fig. 1, in this Plate, we give half elevation of a roof in which

iron and wood are combined (scale in No. 18). Nos. 2 to 14 are various details of this roof, drawn to a scale of 1 in.=1 ft. No. 2 is a side elevation of the cast-iron shoe, as supporting end of rafter *b*, No. 1. In No. 2, *a* is the snug, ear or projecting point to which the end of tie rod *c c* (No. 1) is jointed. No. 3 is the plan and No. 4 the section of shoe. In place of the tie rod being jointed at *a*, it may pass through the shoe, as at *b b*, No. 4, and be secured by the nut *c*. No. 5 is a vertical section of shoe on dotted line (No. 4), *a* being the aperture through which the tie rod passes. No. 6 is section, No. 7 end elevation, No. 8 plan of top, and No. 9 plan of under side of cast-iron shoe, *d* (No. 1), on which the end of collar-beam *c* and upper end of rafter *b b* are housed. No. 10 is elevation and No. 11 sectional plan of cast-iron shoe, *f* (No. 1), which carries the purlin *g*, the shoe being bolted to the side of the rafter *b b*. No. 12 shows the junction of the lower termination of king-bolt and tie rods, at the point *h* in No. 1. In No. 12 *a* is part of king-bolt, which passes through the apertures made in the plates (of which a plan of one is given in No. 13), *b b*, *c c*. The ends of the tie-rods are at *d d*, being finished with circular eyes, as shown in detail at No. 14. These are secured to the plates *b b*, *c c*, by bolts and nuts, as shown in No. 12.

Roofs of Timber and Iron Combined.

We now give illustrations of details of combined work; and first of "straps" of wrought iron used to increase the security of parts of timbers at their points of junction. In figs. 4, 5, 6 and 7, Plate XX., we give various forms of "straps"; these are placed on both sides or faces of the timber—the forms shown in the figures being made in duplicate. They are secured to the timbers either by strong nails or holdfasts, or in superior work screw bolts and nuts are used; the bolts are passed through eyes made in the straps, as in Nos. 1 and 2 in the figure, and also through the timber—the bolt-head butting against the face of the strap, the nut by which the bolt is screwed up butting against the other. Flat keys and cottars are sometimes used to secure the straps and the timber together; a key end is shown in section in the lower part of strap in fig. 4, and the upper part of fig. 5. Of the forms in this figure those to right of fig. 4 and to left of fig. 5 are used to connect the head of a king post with the upper ends of rafters. The strap to right of fig. 5 is used to connect the foot of king post, feet of braces or struts, and tie beam; strap to left of fig. 4 to connect tie beam with foot of brace or strut in a queen-post roof, and these two with the tie beam; strap to left of fig. 6 a collar beam with rafters; fig. 7 ditto; and

strap to right of fig. 6 a straining beam of a queen-post roof with head of brace or strut and with queen post. In fig. 1, Plate XIX, in Nos. 1, 2, and 3, other forms are shown. No 1 illustrates a form of strap for uniting the foot of a king post and the struts or braces; No. 2 a form for uniting the extremities of the "queen post," "brace," and "straining beam"; No. 3 a form for uniting "a collar" with the rafter. In No. 4 *a* is a section of the cast-iron "shoe" which is built into the wall, and receives the end of the beam *b*; *c* is front elevation of the same. Details of roof, drawing No. 1, fig. 2, Plate XVII. No. 5, fig. 1, Plate XIX., shows an elevation of the rafter-shoe, *b*, in No. 1, fig. 2, Plate XVII, and No. 6 a plan. Details of roof No 3, fig. 1, same Plate. No. 7, fig 1, Plate XIX, is elevation of rafter-box, *c*, No. 3, fig 2, Plate XVII., which receives the upper ends of the rafters. No. 8 is a side view of the same. In No. 9, fig. 1, Plate XIX., *a* is side and *b* end elevation of the part marked *d* in No. 3, fig. 2, Plate XVII. The same letters denote similar parts in both figures. Details of roof in No. 4, same Plate. In No. 10, fig 1, Plate XIX., we give side, and in No 11 end elevation of the shoe marked *b* in No. 4, fig. 2, Plate XVII. The rafter-box or shoe *e* will be of similar design to that in No. 7, fig. 2, Plate XIX. Details of roof in No. 5, fig. 1, Plate XVII. No. 12, fig. 1, Plate XIX. is side elevation of "shoe" for receiving the end of the strut *d* and suspension rod *f*, No. 5, fig. 2, Plate XVII. No. 13, fig. 1, Plate XIX., is side elevation, and No. 14 plan, of shoe for receiving end of principal rafter, *g*, and straining beam *a*, No. 5, fig. 2, Plate XVII. No. 15, fig. 1, Plate XIX., is side, and No. 16 end elevation of shoe for receiving end of principal rafter, *g*, and the pole plate *i*, No. 5, fig. 2, Plate XVII. Details of roof in No. 6, fig. 2, same Plate. In No. 17, fig. 1, Plate XIX., we give side, and in No. 18 end elevation of shoe, *a*, for receiving end of strut *b*, suspension rod *c*, and rafter *d*. The rafter shoe, *e*, No. 6, fig. 2, Plate XVII., will be of the same design as No. 7, fig. 1, Plate XIX.; the shoe *f*, No. 6, fig 2, Plate XVII., as No. 12, fig. 1, Plate XIX.; the shoe *g*, No. 6, fig. 2, Plate XVII., the same as No. 10, fig. 1, Plate XIX. No. 19 is plan of shoe in No. 17. No. 20 gives side elevation, and No. 21, fig 1, Plate XIX., plan of a method of securing a beam, *a*, to another, *b*—which it crosses at right angles—by the strap *c*. In No. 22 is given front, and in No 23 side elevation of a shoe, *a*, for receiving the end of a beam, *b*, which is placed horizontally and at right angles to the face of the upright post, *c*. In No. 24 we give side elevation of a cast-iron shoe, *a*, bolted to the side of an upright post, part of which is shown at *b*, to receive the

end of a beam, *c*, acting as a strut or brace. No. 25 is the scale for all the drawings in fig. 1, Plate XIX.

General Framing—Centres.

The special constructions in carpentry of floors, partitions, and roofs having been discussed in the preceding sections, we are now prepared to take up what may be called general constructions, such as centres for arches, bridges, scaffolding, and the like. To those, as well as to the special structures just named, the various forms of joints or methods of arranging and construction, the junction of the several pieces constituting the framing or framework are applicable. We shall take up first the subject of centres for arches—generally called centering—or more frequently and popularly as "centring."

"Centres" are timber framings which serve to support the masonry or brickwork of arches, or curved tops of openings in walls, etc., during their construction, and until the "settlement" of their crowns has rendered them capable of standing alone. From this point of view "centres" are practically scaffolds; they become props when they are put up under old arches which have to be repaired or demolished with precaution, either to prevent the accidents which might happen to workmen, or to save the materials which might be damaged by their fall.

Although "centres" cannot be constructed without the aid of the carpenter, they do not belong so exclusively to his province as other wooden constructions. The engineer who has made the plan of a bridge, and who in consequence knows the resisting powers of the materials employed, should also draw the plans of the centres which he designs.

We, however, give some designs of centres to show the usual arrangements; but there will remain to be determined the proportion of the pieces, which should vary for each construction. A "centre" is composed of a certain number of frames joined together by cross-bars, and on which are fixed horizontally planks or pieces of timber which form the floor of the centre on which the stones or bricks are laid forming the arch. The timber framing may be called a wooden arch, used temporarily to support the materials of the permanent arch. The simplest form of "centre"—that used by bricklayers in "turning the arches," to use the technical phrase, which is constantly done over ordinary door or window openings—is shown in drawing No. 1 of fig. 2, Plate XIX. Close to the jambs, cheeks or reveals of the opening in the wall *a a*, which is to be finished with an arch—semicircular in the drawing (see the volume entitled "The Bricklayer" on arches)—posts or "uprights," as *b b*,

are placed vertically. These are of breadth equal to the thickness of wall where this is small, as in a nine-inch wall; or if the wall be thick, the posts are placed in two sets, one at each side of the wall, front and back, or three posts may be set at side of the opening across the thickness or width of wall. These posts at their upper part carry cross-pieces or wedge blocks, *c c*, and on those rest the lower parts or edges of two pieces of timber, *d*, *d*, the upper surfaces of which are cut to a curve, so that when placed together, butting at the central joint, the surface forms a semicircle which is that of the under side, intrados or soffit of the arch which is to cover or finish at top or upper part the opening in the wall *a a*. These timbers *d*, *d*, carry at intervals cross-pieces, *e*, *e*, termed "bolsters" or "bolster pieces," placed close together, in all cases having intervals less than the width of a brick. On these bolster pieces, as on a timber floor or platform, the bricks are laid, or stones if it be masonry. When the bricks or stones constituting the arch are fairly "settled," or reach what is called their "proper bed" without fear of forcible settlement, the "centering" or "centre" is "struck"—that is, the blocks or wedges *c c* are driven gradually out, which relieves the timber-work above, allowing the masonry or brickwork to settle gradually on its bed. Finally, the wedges are wholly driven out, and the woodwork used to turn other arches of the same form and dimensions. The feet of the posts *b b* are prevented from sinking into the ground in the case of an opening, as that of a door on the ground floor, or made to bear equally on the brick- or mason-work of a window-opening, by their resting upon a cross-piece or sill stretching across the full width of the opening, resting on the ground in one case, and on the brick or stonework in the other. The wedges for driving up and for striking the centre are in some cases placed between this sill and upright posts, in place of putting them as at *c c* in the drawing.

Fig. 2, Plate XIX., in drawing No. 2, represents a more complicated arrangement of centre framework than that shown in No. 1, but still a comparatively simple form, which is used for small arches. It is composed of a tie beam *c*, king post and struts *d*, and curved pieces *e e*, which correspond to the principal rafters of the roof truss. These curved pieces are intended to receive the cross-pieces of timber called the bolsters, as *e e* in No. 1, on which are placed the bricks or stone of the arch. The tie beam is sustained by three posts *f*, *f*, *f*, which are joined to or rest at the foot on another cross-piece on the ground, and called, as we have seen, a sill. It is not absolutely necessary to place the side posts, as *f*, *f*, vertically; they may be inclined, as shown by the dotted lines *g* in drawing No. 2. Acting

in this way as struts or braces, they butt at their feet against the foot or lower part of the central post *f*. The diagram to the right of the centre line *a b* in fig. 2, Plate XIX., No. 2, and that in No. 3, show other arrangements of simple forms of centres. Fig. 6, Plate XVIII., will illustrate the parts and the method of striking the centre of a simple arch, as in No. 2, fig. 2, Plate XIX. In fig. 6, Plate XVIII., *a a* represents part in side elevation of the curved "rib" corresponding to *e*, *b b* the bolsters placed together, or separated as at *e*. The edge view of those parts is shown at *d e*, which is the edge of the rib *a*; two sets of ribs—and in some cases a third or central rib—are used, as at each face, front and back, of wall. The bolster pieces *f*, *h*, *g*, are placed and rest on the edges of the ribs, and are a little longer than the thickness of the wall. The lower part of a "rib" is shown at *i*, resting on a tie beam, part of which is shown at *j*; *k* is the thin end of one wedge, and *l* the thick end of another, both being driven in opposite directions, as shown in side elevation at *p* and *q*. In this *r* corresponds to and is edge view of vertical post *m*, which carries one end of tie beam *j* and end section at *o*, *n* being side view of rib *i*.

In very wide arches we are obliged to employ systems of framework more complicated in proportion as the wood used is in shorter lengths. Figs. 7 and 8, Plate XVIII., represent two designs of centres, which may give some idea of the usual arrangements in this kind of construction. The first, fig. 7, Plate XVIII., is composed of polygons inscribed one within the other; the second has a false tie beam. This latter (fig. 8, Plate XVIII.) may be preferred as being better calculated to resist the pressure of the arch, which is rendered evident when we consider its component parts. It is formed of a tie beam *a*, a false tie beam *h*, a king post *b*, strut or brace *c* to support the false tie beam, a brace *d* placed in the prolongation of *c*, and intended to support the king post *b*, a straining or strengthening sill, *e*, placed on the false tie beam *h* to form a counter-prop at the same time to the king post *b* and the brace *c*, a post *f* supporting the end of the false tie beam; lastly struts, as *b*, serving to keep together the other pieces.

It should be remembered, in the arrangement of a "centre," that it is above all exposed to a very strong lateral pressure; the arch-stones are placed commencing at the bottom of the arch, both sides at once, so that all the strain tends to break the centre in raising its upper part. If this observation is taken into consideration, it will be easy to see the superiority of fig. 8 over that in fig. 7, Plate XVIII. In this latter the oblique strain supported by the joints is considerable, which is a great disadvantage; we are, however, obliged to

employ it when the pieces made use of are not long enough. In this case care must be taken to place in the middle of the centre a weight, which will prevent it rising, and which is increased in proportion as new arch-stones are put on.

The way in which an arch is sustained on the framework of the "centre" during construction depends on the nature of the masonry which composes it. When this is of ashlar or brick work it is supported, as we have seen, on a flooring of planks or pieces of timber exactly the shape of the arch, which is regularly rounded like it, and which serves as a mould for it; then bolster pieces, planks, and pieces of timber are nailed upon the outer surface of each frame, the outer part of which forms a curve concentric to the intrados of the arch.

When the arch is dressed in free-stones which form regular arch-stones, each arch-stone is sustained on the centre by means of bedding blocks. These are long pieces of squared wood laid down horizontally and parallel to the curve of the surface of the arch or vault. They are fixed on double blocks cut in a wedge form, which rest on the outer part of each rib, and enable these pieces to be placed at the exact distance which should separate them from the arch. These blocks are often nailed to the rib, in order that they may remain in the places assigned to them.

Timber Work in Scaffolding.

Resuming illustrations and descriptions of general framework in carpentry, we now take up the subject of "scaffolding." Scaffoldings are timber structures or erections raised above the ground, and are temporarily made use of to facilitate the construction of buildings. They are intended to raise the workmen, the materials, the tools, and the machines to a certain height or to different heights above the ground. They are divided into two classes: simple, and joined or jointed scaffoldings. The first are used for ordinary buildings of the smaller size. For brick buildings they are generally formed by means of large vertical poles, placed parallel to and four to five feet distant from the walls in course of construction, sunk in the ground, and sometimes consolidated by heavy stones, or stones fastened with plaster or mortar. The interspace given to the poles is from five to six feet. They are bound together by horizontal poles, technically called "ledgers," which are fastened by ropes to the vertical poles, and at a height corresponding to the required level of the first platform or working stage. These ledgers are also intended to prevent the erection moving, and to bear other transverse and short poles or pieces called "putlogs," which are also bound to the poles at one

end with ropes, and at the other fixed to the wall in course of construction. Upon these cross-beams of timber planks are laid, to form the stage or flooring upon which are to be put the materials used in the building.

Scaffoldings of this kind often consist of several stories placed one upon the other in proportion as the building progresses. When the poles are not sufficiently long to reach the top of the building, they are lengthened with other poles attached to the first with ropes till they reach the desired height.

The holes made or left in the brick wall for the "putlogs" are stopped up in proportion as the scaffolding is taken to pieces, which is done by commencing with the upper part. But when we wish to avoid making holes in the walls—which always injures them more or less, and which is sometimes not easily practicable—one is obliged to use, to keep up the stages or platforms, a double row of posts, which are then placed along the wall; or, better still, to rest the latter on the window-sills, fastening them in the inside, as space permits, to prevent the scaffolding upsetting. We may also, for the case in question, rest some of them on the projecting parts of the wall when there are any.

Joined or jointed scaffoldings are those employed for large buildings. They are when large constructed with heavy squared timbers, technically called "balks," so that they may be strong enough to resist the very heavy weights they sometimes have to bear, such as blocks of stone, machines serving to elevate the materials, etc. They are arranged like the preceding scaffoldings, and are formed of uprights or pieces of wood placed vertically, sunk and made fast in the ground five feet or so distant from the wall. They are often supported by other timbers stretched horizontally on the ground, serving in the same way as wall plates in roofs. These uprights are bound together by other pieces placed horizontally, on which rest the small joists which are to receive the flooring boards or stage planks. The framework is resolved into triangles, on the principle of the truss, in order to give more solidity or firmness to these scaffolds, by means of straining sills, struts or braces, etc. One should, as far as possible, avoid using too great a number of pieces—always injurious to the solid execution of work. In good building a scaffolding should be simple, solid, and adapted in every respect to the use for which it is intended. The different pieces which form it may be joined with the simpler forms of joints in the "half-lap," or even with tenon and mortise joints. We must, however, avoid unnecessarily cutting up the pieces, so that they may be used for other purposes without too great loss.

We may give to scaffoldings forms different from those that we have just described. For example, they may be suspended, either to avoid obstructing the public road, or when the building in course of construction is on the brink of water. They may also be adapted to the interior work of large houses; but it is impossible to give a description of them here, because their combinations may be varied *ad infinitum*, according to the nature of the work to be done, the weight of the materials, the number of the workmen, and the peculiarities of the place. It is from these considerations that the architect or the master carpenter must judge for himself of the means to be employed to put up wholly and suitably this kind of apparatus.

In fig. 9, Plate XVIII, we give illustrations of different forms of scaffolding used in the construction of large undertakings, such as public works. In fig. 9, Plate XVIII, we give elevations of two forms of the kind of scaffolding known as "gantries." This is composed of a beam *a a*, as in drawing to the left, in which a "travelling crane"—hand wrought or steam worked as the case may be—is supported at a height above the work to be done sufficient to give ample space for lifting or working. The beam *a a* carries iron rails, along which the wheels of the "traveller" run; two beams being placed parallel to each other, and of course at a distance corresponding to the working space beneath, and over which the traveller is carried or spans. The beam *a a* is formed in lengths joined to each other, so that the desired length of travel is obtained; one row of beams being placed at one side of the working space, one row at the opposite side, and perfectly parallel to each other. Those beams are carried on, or supported by, vertical beams placed as posts at intervals, as *b b*. These are sunk at feet a short distance into the ground, and, if this be loose, may rest upon stone or timber plates. From what has been said of the principle of the "truss," this form of scaffolding or gantry will depend for its stability solely upon the strength of the vertical posts, their fixedness in the soil, and the secure way in which the beams are connected to the posts acting, as the beams *a a* will act, as ties. The correct way of forming a strong structure of this kind is by resolving the quadrilateral-sided spaces, as in drawing to the left of fig. 9, Plate XVIII., into a series of triangles, by running braces or struts diagonally, as *h h*, from one post to the other, or two braces crossing each other, as in fig. 2, Plate XXI. This last arrangement is partly shown at the foot of post *g* in fig. 9, Plate XVIII. Short struts or braces may be used, as shown at *f f* in this figure. The drawings to right of fig. 1, Plate XXI., and fig. 2, same Plate, illustrate other forms of

scaffolds used in large work; fig. 1 being that used in the construction of a breakwater for delivering material right and left.

The pieces of wood which serve as a temporary support to the upper parts of a building when we "underpin" the walls or any part of them, or when we make in a façade a shop-door or a carriage entrance, keeping out, in consequence, one or two piers of the ground-floor to replace them by a breast-summer or a girder, assume different forms according to the nature of the work of "underpinning." In fig. 4, Plate XXI., we give an example of a framing for a certain class of underpinning.

The timbers used in underpinning have sometimes very considerable weights to bear: that of a whole façade, of floors, etc. It is therefore necessary that they should be joined together in such a way as to replace the support given by the wall or that part of the wall which has to be demolished; it is also necessary that the pieces should be of a sufficiently strong section, that none of them should tend to counteract the effect of the others, and that they should all contribute to the same end, which is, to sustain and maintain equally all the parts requiring to be propped.

It would be difficult to give fixed rules on the mode of joining the pieces which should form a framing for underpinning. Experience only can teach how they should be placed, for their arrangement must vary according to circumstances. But, in general, we must pay regard to what has already been said about avoiding the use of too great a quantity of wood, for it would unnecessarily increase the expense, besides impeding by too much wastefulness the free execution of the work.

When an opening has to be made, say as for a shop-front or a carriage entrance, taking away part of the wall of the ground-floor, we commence, to prevent shaking in the upper parts of the wall, by placing along the jambs of the window openings, if any, above, and which correspond to the opening to be made, pieces standing vertically, and jamming them up against the sides or reveals of the opening, which are supported or kept apart by several diagonal pieces or props sloped alternately in contrary directions.

Several holes in the wall are then cut out below to receive strong pieces or beams of wood projecting some distance in each side of the wall. These cross-pieces are supported at each end by two posts placed obliquely or sloped in the contrary direction, as at *e e e e*, in fig. 1, Plate XXI. (to right of figure). We then take away the part of the wall intended for the opening, and put in the girder or the breast-summer, which should be supported at its ends by the jambs of the opening. The posts or standards are placed on timber-

plates; the foot is bevelled on both sides, and in order that they may be supported entirely by the plate wedges fastened with nails are used.

There are combinations of timber work employed for a wide variety of work, such as is met with in the practice of masonry; some of these will be found illustrated in the volume dealing with the work of "The Mason"; others, as simple bridges, will be illustrated presently in this volume. We give in fig. 7, Plate VI., a sketch illustrative of a species of scaffolded floor which has to sustain heavy machinery; this being the elevation, and fig. 6, Plate VI., the plan, and fig. 6, Plate VI., being the elevation of end.

Buildings under repair, or in a shaky condition, are secured or propped up by a modification of timber scaffolding to which the name of "shoring up" timber is given. "Shoring up" is also often required in making the excavations for foundations, if those be deep; in making the cuttings for sewers, cuttings for roads, etc., till the retaining walls used in the latter can be built. In fig. 4. Plate XXI., *a b c* illustrates a simple form of "shoring up" the exposed face of a cutting—boarding being pressed up against the face of cutting—and this being kept in place by the struts or braces *c*, *c*. The diagram at *d e*, *f g*, shows two methods of securing the feet of the braces. The diagram to the right illustrates a trussed arrangement of timber pieces used in shoring up the side of a house; diagonal struts, as *k* and *l*, being used in addition to the oblique or sloping main pieces. The diagram at the bottom represents two methods of shoring up excavations for sewers in watercourses. In the smaller cutting to the left the sides are supported by boarding or planking, *n n*, kept apart by horizontal or straining pieces, *o*, *p*; in the other cutting two verticals, *q*, *q*, are supported by the diagonals *s*, *t*, and pieces *t*, *r*.

Timber Construction in Bridges.

"Gangways" and "foot bridges" are still frequently made of timber, the latter especially in rural districts, where larger structures, as those having a single cart or carriage way, may be made of the same material. The simplest form of "gangway" used, for example, to secure communication between two buildings separated from, but not far away from, each other is that shown in upper diagram in fig. 5, Plate XXI. This is made with two beams, as *a*, *a*, one placed at a distance from the other equal to the desired width of footway or platform, but both parallel to each other; these span the opening *b b*, and carry the cross-boards forming the footway, a light hand-railing being put up on each side of the footway. But unless

the beams *a, a*, be very strong—and the weight would increase with the strength—the tendency of the weight thrown upon the gangway, as that indeed of the beams themselves, would be to cause them to bend or "belly" downwards, as shown roughly by the dotted lines. The simplest method to prevent this, and make much lighter beams as strong, is illustrated by the beam *d d*, braced by the struts *e, e*, the lower part of these bearing or butting against the sides of opening *f f*; *g* shows two of the rails with part of the handrail joining the tops. A "framed gangway" is shown in the third drawing in fig. 5, Plate XXI., on the "king-post," and another in the fourth drawing on the "queen-post" truss principle. In both of those trusses the framework stands above the level of the approach on either side, the footway planks resting upon the upper faces of the beam, *h h* and *m m*; the side supports or protection posts are formed by the king post *j*, queen posts *o, o*, the struts or braces *k k*, *s*, and upper rail or piece *i i*, *n n*, so that small handrails may be dispensed with, or, if used, used only to fill in the parts as shown at *l* and *u*, or partly filled in. For comparatively short spans or narrow void spaces to be bridged over, the simple form of single trussed beams will suffice, such as we illustrate in figs. 5, 6, and 7, Plate IX., or as in figs. 7 and 8, Plate VIII.

These forms of trusses may be used for foot-bridges of considerable span, crossing streams and small rivers. But for wider spans special trusses should be designed, which will give not only stronger forms, but structures presenting a more pleasing appearance to the eye than either the king-post or queen-post truss in fig. 5, Plate XXI. Fig. 6, Plate XXI, gives an example of Continental construction still met with in some of the old fortified towns, where the moat has to be crossed by a gangway or bridge, provided with a lift-up swing bridge, as shown at right hand of drawing. The part to the left gives a good illustration of a ganting scaffolding, described in a preceding paragraph, and the upper part offers a neat example of a strong hand or side protecting rail, fitted for cases where there is horse and carriage as well as foot traffic.

In fig. 2, Plate XIX., we give in Nos. 4 to 8 inclusive drawings to scale of foot-bridges. In Plates XXII., XXIII., and XXIV. we give sketches illustrative of Continental work in timber and stone, for which we are indebted to one of the best Continental authorities on building construction; and in other plates we give various parts of carpenter's work in connection with house construction, roofs, bay-windows, and the like.

The preceding paragraphs have been all taken up in the illustrating

and description of the various departments of what is called practical carpentry—that is, embracing all the points connected with the actual construction of timber work (employing this term here as including not only the arrangements of timbers employed in the formation of what is called framed work—such as floors, partitions, roofs, bridges, and the like—but also the details of the parts of which they are composed), as illustrating the way in which those parts are joined together so as to constitute the general framing of which they are the individual members.

With the exception of remarks here and there incidentally made—as, for example, on trussing, in the chapters treating upon roofs—we have not yet gone into the principles upon which framework is *designed.* It is to this department we now direct the attention of the reader.

General Principles of Timber Framing Design.

Where a post of timber or column of iron—as *a*, No. 1, fig. 1, Plate XXV.—is pressed upon by a weight *b* resting upon the top, the post or column is subjected to what is called a compressile strain; and its strength to resist this is called its resistance to compression. When a piece of timber or iron rod—*a*, No. 2—is pulled by two opposite forces in the direction of its length, as by the weights, as at *c*, acting on the chains passing over the pulleys *b*, the part *a* is said to be subjected to a tensile strain; and its strength to resist this is called its resistance to tension. When a beam *a*, resting at its extremities on two supports, *b*, *b*, No. 3, fig. 1, Plate XXV., is pressed upon by a weight, as *c*, or the hanging weight *d*, it is said to be subjected to a cross or transverse strain; and its strength to resist this is called its resistance to cross strains.

The Neutral Axis of a Beam.

When a beam is placed under the circumstances illustrated in No. 3, it has a tendency to bend in the centre, assuming the form of an inverted bow. This effect is known as the deflection of the beam, its capability to resist it being termed its resiliency or elasticity. The upper and under sides of a beam are under different kinds of strain; the upper side being subjected to compression, the under to tension. This is illustrated in No. 4, where *a* is part of a beam, with two saw-cuts made in the upper and under sides. When the beam is supported at the ends the upper saw-cut closes, the strain of compression being towards *b*, as shown by the arrows, the lower saw-cut opening, the strain of tension being from *c*, as shown by the arrows. That part of the beam, the fibres of which

are not subjected to either tension or compression, is known as the neutral axis of the beam, and is nearly midway between the upper and lower sides, as at *a*.

Strains to which the Materials of a Roof Truss are Subjected.

The strains above noticed are called into existence in the parts of a roof truss. Thus, in No. 5, the rafters *a*, *a*, are subjected to compression; the king post *b* to tension, as also the tie beam *c*. Under certain circumstances the tie beam *c* may be subjected to a cross strain; this is, however, avoided in a well-designed truss. No. 6, fig. 1, Plate XXV., illustrates these pressures more distinctly; for the rafters *a*, *a*, No. 5, may be dispensed with, and their place taken by a series of blocks, *a*, *a*, No. 6. These, being all pressed together in the direction of the arrows, are kept in position by pressure only, which would not be the case if the strain were other than that of compression. In like manner the solid beam *c*, No. 5, may be dispensed with, and its place taken by a chain, *b*, connected at its extremities to the two last of the series of the blocks *a*, *a*. Being subjected to tension, it is stretched the tighter as the pressure of the weight *c* on the blocks *a*, *a*, increases. The office of the king post *b* in No. 5 may be performed also by a chain, as *d* in No. 6. The arrangement of parts in Nos. 5 and 6 constitutes what is called a truss, the strongest of all assemblages of beams, and the capability of which to resist pressure is limited only by the strength of the materials of which it is composed, and the nature of the joints and fastenings used to keep the parts together.

General Principles of Framing.—Pressure of Inclined Beams.

Inclined beams forming the distinguishing feature of the "truss," it is of importance to know the methods by which the amount of pressure to which they are subjected is ascertained, and the direction in which a pressure is transmitted to a beam or an assemblage of beams. These methods will be explained in connection with the remaining drawings in fig. 1, Plate XXV., and fig. 2, same Plate, yet to be described Let us imagine a ball, *a*, No. 7, fig. 1, Plate XXV., to be propelled or pressed in the direction of either on the arrows *b* or *c*. If pressed singly in either direction the ball would travel towards *b* or *c*, but if equal forces were pressing simultaneously on the ball *a*, in the direction of *b* and *c*, the ball would follow neither line of advance, but would take the direction of a diagonal *a d*. The two forces, *b* and *c*, being equal, the line *a d* would be the diagonal of a square, of which *a e* is the side. If, however, one force tending to send the ball *a*, No. 8, in the direction of *b*,

were equal to twice the amount of another pressure, represented by the arrow *c*, the ball would go off in the direction of the diagonal, *a d*, of a parallelogram, the length of which is *a e* and breadth *a f*. This diagonal, *a d*, is called the resultant of the component forces, *a c*, *a b*. When we wish to find the pressure of any one force, as *a d*, No. 7, which shall be equal to the pressure of two, as *a c*, *a b*, the operation is said to be the "composition" of forces; while the "resolution" of forces is the converse of this, and consists in ascertaining two forces, *ac*, *a b*, which shall equal the pressure, of a single force, as *a d*. The application of the composition and resolution of forces to the combinations of carpentry we now purpose to illustrate. The pressure which the beam *a*, No. 1, fig. 1, Plate XXV., sustains, is easily measured by the weight *b*, which rests upon it, but where two pieces, *a*, *a*, No. 6, inclined at equal angles, sustain the weight *c*, the angles being equal, the pressure sustained by each beam is equal; though the amount of pressure transmitted by both is greater than the weight *c*, and this in proportion as the distance between the lower extremities of the beams on *e e* is increased. This is illustrated by No. 9. Let *a b*, *a c*, be the two inclined beams, pressed at their apex, *a*, by a weight of say 14 cwt.; drop a perpendicular, *a d*, and make its length, taken from any scale of equal parts, equal to 14. Then, from the point *d*, draw *d e* parallel to *a b*, and from same point *d*, *d f* parallel to *a c*. Measure *a f* from the same scale as *a d* is taken from; with the degree of inclination given to the beams in the figure, *a f* will be found to be equal to 9, which is the amount of pressure sustained by the beam *a b*. The pressure on the beam *a c* is the same as this, their united pressure being 18 instead of 14, which the weight would exercise on a vertical beam, as *a*, No. 1, fig. 1, Plate XXV. As the inclination of the two beams increases, the united pressure transmitted through them increases. This is illustrated in drawings Nos. 10 and 11. The pressure exerted on the apex of the two beams, *a b*, *a c*, being the same as in No. 9, the amount of pressure on the beam *a b*, No. 10, is 10: united pressure, 20. The pressure on the beam *a b*, No. 11, is 11: united pressure, 22. Two pieces placed at different angles sustain different pressures. Let *a b*, *a c*, No. 12, be the two pieces inclined at different angles, and which we suppose to be pressed upon at their apex, *a*, by a weight say of 12 cwt. Drop the perpendicular *a d*, make it equal to 12, from the scale; draw *d e* and *d f*, parallel to *a b* and *a c*; the pressure on the piece *a b* will be found to be equal to $6\frac{1}{2}$, and that on *a c*, $7\frac{1}{2}$: together, 14 cwt. The pressure on the apex of the two beams *a b*, *a c*, No. 13, being 10 cwt., that on the beam *a b* will be found to be 5, that on *a c*, $7\frac{1}{2}$: together, $12\frac{1}{2}$.

These figures, No. 9 to 13 inclusive, fig. 1, Plate XXV., are all illustrations of the resolution of forces—finding two forces which, acting in different directions, are equivalent to one. We now propose to glance at the application of the "composition of forces"—finding the amount and direction of one which will be equivalent to two forces. Let *a*, drawing No. 14, fig. 1, Plate XXV., be a beam pressed upon by a force equal to 6 tons, and *b* another pressed by a force of 9 tons: it is desired to find the direction of a beam which shall be opposed to resist these forces, and also to ascertain the amount of pressure which this third beam will sustain. Continue the central lines or neutral axes of the beams to *c* and *d*, make *e d* equal to 9, and *e c* to 6; complete the parallelogram by making *d f* parallel and equal to *e c*, and *f c* to *d e*. Draw the diagonal *e f*, which will give the direction in which the piece *f* must be placed to support the strain of *a* and *b*. By measuring the length of the diagonal *e f* from the scale from which *e d* is taken, the amount of pressure which the piece *f* sustains will be found equal to 11. In drawing No. 1, fig. 2, Plate XXV., the composition of forces is also illustrated, *a* being the direction of a third piece, to sustain the pressure of two inclined beams, *b*, *c*, each exerting a pressure of 12 tons, the distance, *d e*, giving the amount of pressure, 18 tons, which it sustains. The tendency of the pressure of the two beams, as *a b*, *a c*, No. 2, is to thrust the walls on which they may rest outwards, as shown by the arrows. The amount of pressure exerted on the walls in this way is ascertained as follows: Let *a d*, No. 4, be equal to the pressure on the apex, say 14 cwt.; from *d* draw *d e*, *d f*, parallel to *a b*, *a e*; join *e f*; *e g* represents the pressure exerted on the wall *c*, tending to thrust it outwards; *g f* is equal to *d i*. The pressure exerted on the ends of the tie beam *a b*, No. 3, fig. 2, Plate XXV., tending to pull it asunder, may be estimated as follows: From *c* drop a perpendicular, and make *c d* equal to the weight acting on the apex of the two beams *c a*, *c b*; complete the parallelogram. At right angles to *c d* draw from the point *e* the line *e h*, and from *f* the line *f g*; measure *f g* or *e h*, and the distance 5 will represent the pressure exerted by the feet of the beams on the tie beam *b a*. In the case of two beams resting on walls, as in drawing No. 3 or No. 6, fig. 2, Plate XXV., each beam presses on the wall in the direction of its own length—that is, obliquely; but this oblique thrust is resolvable into two parts, one horizontal, tending to push the wall outwards, the other perpendicular; and the use of the tie beam, as *b c*, No. 6, is to sustain and counteract the outward part of the thrust, and leave only the vertical part to be sustained by the wall. To estimate the horizontal and vertical pressures at the feet of inclined beams,

proceed thus: Let *a b*, No. 5, be the central line of combination, and *a c* one of the inclined beams; continue the line *a c* to *d*; from *c* and *d* draw lines *d e*, *c e*, parallel to *b c* and *b a*; complete the parallelogram *c e d f*. The distance *c f* taken from a scale will give the amount of pressure $5\frac{1}{2}$ in the horizontal direction *c f*; the distance *c e*, from the same scale, the pressure 7 in the vertical direction *c e*. In No. 5, fig 2, Plate XXV., the vertical pressure, *c e*, is equal to $5\frac{3}{4}$; the horizontal, *c d*, to $6\frac{1}{2}$. Where inclined beams, as *a a*, drawing No. 6, fig. 1, Plate XXV., are loaded by a weight at their apex, as *c*, the pressure is transmitted in the direction of the length of the beam; but, as in roofs, the covering—as slates, tiles, etc.—is distributed over the whole surface of the beam, the pressure at the foot is considerably out of this line. To ascertain the pressure under these circumstances proceed thus: Let *a b*, *a c*, No. 6, fig. 2, Plate XXV., be two inclined beams; and let *d*, *d*, be the points indicating the centres of gravity of the beams. Through *d* draw a line *f g*, parallel to the line *a e*; from the point *a* draw a line *g a*, parallel to the line *b c*; join *g b*; *g b* shows the direction of the thrust on the wall *b*. To ascertain the amount of the pressure from *g*, set off on the line *g f* a distance *g h*, equal to the weight of materials on the beam *a b* (say 10); from *h*, at right angles to *g f*, draw a line *h i*, cutting *g b* in *i*. The distance *h i*, $5\frac{1}{4}$, is the amount of the outward thrust on the wall exerted by the beam *a b*. If the weight is 15, represented by the distance *h l*, the pressure on the beam *a c* is $7\frac{1}{2}$. In No. 7, fig. 2, Plate XXV., this method of ascertaining the amount and direction of pressure on uniformly loaded beams is shown in connection with an assemblage where the beams *a b*, *a c*, are of different inclinations. The weight of materials on the beam *a b* being represented by the distance $d\,e = 15$, the lateral pressure of the beam *a b* is represented by the distance $d\,f = 8\frac{3}{4}$; the weight on *a c* being $g\,h = 15$, the pressure is $h\,i = 6$. When two beams, *a*, *b*, No. 8, fig. 2, Plate XXV., projecting from wall, are subjected to strain by a weight acting in the direction *c d*, the amount of pressure sustained by each piece is ascertained thus: Let *c d* be the amount of weight, say 12 tons: continue the axis of the piece *a c* to *e*; from *d*, parallel to *a c*, draw a line *d e*, and another parallel to *c b* to *e*. The distance *c e* will be the measure of the pressure on the part *a*, tending to pull it out of the wall—a tensile strain; the distance *c b*, that on the beam *b*, tending to push it into the wall—a compressile strain; with the particular inclinations given in the figure, *c e* will be found to be $15\frac{1}{2}$, and *c b* $14\frac{1}{2}$. Drawings No. 9 and 10, fig. 2, Plate XXV., are examples, showing different arrangements. The pupil should measure the distances *a b*, and

from same scale ascertain the pressures *a c*, *a d*. In No. 11, the best position of the strut *a*, to support the beam *b*, acted upon by a weight in the direction of *c*, is in the direction of the diagonal *a d*. This is ascertained by completing the square, of which *c d* is the side. To resist tensile strains, wrought iron is a better material than wood or cast iron; while wood and cast iron are better calculated to resist compression, for which indeed wrought iron is unfitted. To know, then, where to use a material best fitted for the strain to which it is subjected, it is necessary to ascertain whether the part into which it is to be made is subjected to a "compressile" or a "tensile" strain. Parts subjected to the former are generally in technical language called "struts" or "braces"; those to a tensile strain, "ties." To ascertain, then, whether a part acts as a strut or tie, take the following rule, given in the article "Carpentry," *Encyclo. Britannica.* Construct the parallelogram of forces according to the pressure exerted by the weight, as *a b*, *c d*, No. 12; then, if one side of the parallelogram, as *d c*, parallel to one of the pieces, as *a*, cuts a line produced from the other piece *b*, that other piece acts as a tie; if the line, as *d a*, parallel to one piece *b*, cuts the other piece *a b*, the piece *a b* acts as a strut. Thus, where the line cuts the piece itself, that piece acts as a strut; if it only cuts a line produced from the piece, that piece acts as a tie. Another method is to ascertain the direction in which the weight would naturally fall, as *b* in the direction of *b d*. Through the point *b*, parallel to *a c*, draw a line *e f*: the piece above the line *e f* acts as a tie, the piece below it as a strut. No. 13 shows another combination of beams, and how the piece *b g* acts as a tie and the piece *b a* as a strut.

Some of our young readers may have an idea that in the matter of beams, if the dimensions be considered sufficient—either as shown by experience or more accurately by calculation—to resist certain strains and pressures, it matters little how they are employed:—that is, supposing a beam to be *per se* (by itself) strong enough, it will make no practical difference whether its position be such that it lies or rests upon its flat side or upon its edge. It should here be noted that, with the exception of posts or columns of timber, all beams properly so called are cut out of the log, or so formed or made of a single branch or bole of a tree that their depth, as *c d* in drawing No. 3, Plate XXVI., is greater than their breadth, *c b*. This gives them the form of a rectangle or parallelogram, as seen in their end view or at any line of cross-section. This very form or "section" —to use the technical phrase—is that which arises from the fact that it is not a matter of indifference how a beam is laid to resist strains or pressure; on the contrary, that it is the fact that a beam laid

on the flat is much less capable of resisting the strains of cross or transverse pressure than when laid on the edge. And the reason why posts or columns of timber are made square is not that they look better—although this point is not without its due weight—but because they have to resist the strain of compression only. Let us look further into this matter; and in doing so we shall extend our remarks to the case of iron beams as introductory to what is given on the construction of roofs, etc., of iron. And first as to square and rectangular beams. The transverse strength of a rectangular beam—as *a*, No. 2, Plate XXVI.—is as the square of the depth multiplied by the breadth and divided by the length. The strength of beams thus increases only in the simple ratio of the thickness, but as the square of the depth. Thus, the beam *a*, No. 3, is much stronger than the beam *a*, No. 2, although the dimensions are equal in both cases. The increase of strength obtained by placing rectangular beams on their edge instead of on the flat—or in other words increasing their depth in a much greater proportion than their thickness—may be seen from the following: Let the breadth *b c*, No. 2, be equal to 12 inches, and the depth *c d* to 6; the distance between the supports 8 feet: the strength of the beam would be represented by 54, this being obtained by squaring the depth, multiplying it by the breadth and dividing it by the span. But by laying the beam on its edge, as represented in No. 3, its strength will be represented by 108. In No. 1 *b* is part side elevation of *a*, No. 4 being part side elevation of the beam *a*, No. 3.

Where a beam *a b* supported at both ends is loaded in the centre, as by the weight *c*, No. 5, Plate XXVI., it will only bear half the weight which it would do if this were distributed over the entire the weight which it would do if this were distributed over the entire surface of the beam, as illustrated by the diagram in No. 6. The pressure exercised upon a beam by weights resting on it, being different at different points (the pressure, for example, exercised by the weight *a*, No 7, is less than that exercised by *b*, and by *c* greater than by *a*), it follows that where the material admits of it, a beam may be made of the form represented in No. 8, the under side being a parabolic curve without its strength being diminished. The depth diminishes towards the ends just as the liability to fracture diminishes, and thus there is no waste of material. For the convenience of firmly fixing the beam, the ends do not come to a point, as at fig. 8, but are finished as at *a a* in No 9. A beam projecting from a wall, and loaded at the end as at No. 10, will carry half as much only as the beam in No. 11, where the weights are distributed uniformly over the surface. Compared with the beam as in No. 5, that in No. 10 would only carry one-fourth the weight. The beam *a*, with

the load at the end, as in No. 12, Plate XXVI., is as strong as that in No. 10, so that one-third of the material may be saved by adopting the form in No. 12, without any diminution of strength. When the beam is uniformly loaded, as in drawing No. 15, Plate XXVI., one-half of the material may be saved, and as strong a beam obtained, as in No. 10, by making it triangular. The drawing in No. 13 shows the parabolic beam uniformly loaded, and fig 14 the triangular beam loaded at one end. The drawing in No. 16, fig. 3, shows Tredgold's "I"-shaped cast-iron beam, fig. 17 being a side elevation; No. 18, the "Hodgkinson" beam, the strongest and best form. The ratio of the strength of the beam in No. 18, as compared with that in No. 16, is as 4075 to 2368. For a beam of section as in No. 18, the best proportions are when the bottom flange contains six times the area of the top one and two-thirds of the entire area. The drawing in No. 19, fig. 3, Plate XXVI., is a part side-elevation of No. 18. If a beam of cast iron, of section as in drawing No. 18, is placed with the broad flange uppermost, as in No. 20, its strength is so much reduced that it will only support about one-third of the amount which it would bear if placed as in the drawing in No. 18.

The drawing in No. 21, Plate XXVI., illustrates in side elevation a beam made of cast iron of the section shown in No. 18 drawing. In No. 21, *aa* represents the part *a* in No. 18, which is called the "web" or central plate, *b b* the upper flange, and *c c* the lower flange, corresponding to parts similarly lettered in No. 18. In No. 22 we give the plan—with scale to which it is drawn under it—of top of the cast-iron beam as looked down vertically upon. The letters in No. 22 indicate corresponding parts in Nos. 21 and 18. The dotted lines show how the upper edge and flange is curved, an arrangement sometimes adopted to save metal or to make the outline of the beam more pleasing to the eye than if quite straight along, as in No. 21. Wrought-iron beams for small spans and light work are of sections in varying forms, but of which the section in No. 23 is a representative form. When wrought-iron beams are used for large spans and to bear heavy weights, they are what are technically called "built beams." That is, in place of being rolled solid, as in drawing No. 23, they are made up of several pieces, as in No. 24—cross section, and in No. 25, which is part side-elevation. The main part of the "built beam" consists of a large and broad plate of thickish wrought iron, dimensions of which are all found by calculation. This is shown in its normal or vertical position at *a a*, Nos. 24 and 25. Along the lower or bottom edge of this central plate, which is technically called the "web," two "angle irons," as

b, *b*, are riveted, as shown in the drawings, and the same is done at the top. Where wrought-iron beams are used for wide spans, and to resist great strains or support great weights, a form known as the "box beam" is sometimes used. This is illustrated in the drawing No. 26 in Plate XXVI., and is made up of two vertical side plates, *a a*, placed vertically, and kept some distance apart by the top plate *b* and the bottom plate *c*, on which latter the beam rests, as its base or foundation. The whole are secured and kept in place by the angle irons, as shown. This beam, introduced by the celebrated engineer Sir William Fairbairn—and deduced by him from elaborate investigations and experiments made in conjunction with the well-known scientist Mr. Eaton Hodgkinson—is very strong, but it possesses this great disadvantage: that from the general inaccessibility of its interior parts, those are apt to be left to the ravages of rust, which cannot thus be combated in the usual way. The form of beam in drawings Nos. 24 and 25 does not present the same practical difficulty, as all its surfaces, being exposed, can be painted or otherwise treated in order to prevent the action of rust, to which wrought iron is much more liable than cast iron. But in this form the "built beam" is applicable to but limited spans, and cases where comparatively small weights are to be supported or carried. Where very strong beams are required, such as would otherwise be obtained by adopting the "box beam" in No. 26, the disadvantages of this are met by having the beam arranged in the form known as the "lattice girder." In this the web, as *a a* in Nos. 24 and 25, is not made up of a solid or continuous plate, but of narrow wrought-iron bars, crossed so as to form a species of network or lattice-work—hence the name.

Timber or Wood the Material used by the Carpenter, Joiner, and Cabinet Maker.

Of all the materials with which nature has so abundantly supplied him, used by man for the varied purposes of his life, timber, or, to employ the more generally used term, wood, has played a most important part. In the early stages of his civilisation, when the tools and appliances at his command were few in number and simple, and of necessity inefficient in working character, the comparative ease with which it could be worked into the simple forms which he would then require to satisfy his equally simple wants would make wood or timber the most valuable material for the purposes of construction. Nor less would this be the case from the abundant supplies of it with which from the earliest times he would on every hand be provided. For there is every reason to suppose

that in those early times, and coming down indeed to periods closely approaching our own—for, in the history of peoples generations, nay, even centuries, are but as days to the individual—the greater portion of the surface of the earth in those countries in which man found his abode was covered with forests more or less dense. And it would be to the woods and forests that men would at first naturally resort at once for protection from their marauding enemies, for shelter from the inclemencies of the weather, whether that was the burning heat of the sun or the colds of blustering winds and rain, and for the abundance of food products with which the forests abounded.

Under the shade and shelter of the trees of the forest, or that less dense and tangled of the lesser woods and plantations, the demand for special structures carefully constructed to resist winds, to repel rain, and to keep out cold, would naturally be less than in the exposed localities of the open plains or prairies. The further that man penetrated into the dense forest regions the more secure would be his shelter, and the more easily would he obtain that further and higher degree of it which the mere contiguity of huge trunks and wide-spreading branches and dense foliage would give him. A few branches broken off from the parent tree, and forced or pressed into the yielding soil, soft with the accumulated decay of vegetable matter of years, would give him all the shelter which his more or less savage condition would demand or could indeed supply. But as civilisation progressed and as population increased, and the stern necessities of mere existence demanded large and still larger supplies of food of a kind more to be relied upon than the scanty and precarious and at best simple and nutritious chance products of the woods, man would leave the forests and take to the plains and open glades, there to cultivate the soil and raise such food products as best he could at first. And for the obvious purposes of defence against enemies in those earlier times of the world's history, ever ready to descend upon communities, generally for purposes of plunder, but often from a mere wanton love of destruction, the cultivated grounds would be within the near vicinity of the forests. But as the population still further increased and civilisation progressed, the open ground would be extended, its boundaries would advance, and in proportion those of the woods and forests would recede. There would thus in process of time be an antagonism, so to call it, created as between the open and cultivated or cultivable spaces, and the forests by which they would be more or less closely surrounded. The effect of this in its later and ultimate stages on what is now known as the supply of timber will be hereafter more fully referred to.

But with the open spaces, the widespread plains, or the exposed hill sides, which man in his advanced condition of life would be compelled to occupy as his "living places," would come of necessity demands for structures affording special shelter from the seasons and means of defence from foes. With tools and appliances long of the simplest and least efficient character, incapable of dealing with hard and obdurate materials in order to give them such shape and form as his daily requirements demanded, wood, being the "freest to work," would be the material most in favour with the earliest constructors, alike for the larger parts of houses, as for the less bulky fittings of the interior. And as his knowledge increased, and with it his tools and appliances, he would be able to erect the still larger and more durable structures, and to construct still more costly and complicated fittings, which the necessities of a higher civilisation would demand.

Timber or wood thus became one of the most important materials used for all the wide varieties of structures required by man alike for the purposes of the arts of peace or of war. And this position it maintained for a long course of years But this supremacy, as a material lending itself in the readiest and most facile of ways to all the purposes of construction, has of late been threatened, and indeed to a large extent practically invaded, by the extended use of iron (see the companion volume in this series containing "The Iron and Steel Maker"); and this is likely to be still more marked by the increased constructive facilities offered by the modern forms of steel. Yet, notwithstanding this threatening of the supremacy which timber has so long enjoyed as a facile material for construction, it seems as if in its case another exemplification of the truth of the old proverb is to be afforded, that a "threatened man lives long." For, to judge from what is going on around us, there seems to be no less a demand now for the various products in which the timber merchant deals than existed years ago, when iron, either in its form of cast or wrought, was rarely used for large constructions, and steel in the modern form, in which alone it could be available for the like, was altogether unknown. And in this connection the following curious circumstance is worthy of special note here, as bearing most closely on the present position of the timber trade, if not upon its future condition. For, largely increased as has been the employment of iron in its higher and more valuable form known as wrought or malleable, and of steel in its modern form known by the name of "mild" ("Bessemer" or "Siemens" steel) in the varied work of the civil engineer and the architect—as, for example, in bridge building, and in the construction of large roofs—the engineer and the architect

would make but little progress in those metallic structures unless the timber dealer and the carpenter came to his aid. Those of our readers who have examined the progress of such large works must have noticed the extensive way in which timber is employed by way of scaffolding, without which the iron or steel bridge, viaduct, or roof of wide span could not be erected. The metal, under the new *régime* of construction, may have thus far taken the place of the timber, which in former days was the material alone used for the permanent structure—the bridge, the viaduct, or the wide-spanned roof; but without the timber, as an essentially necessary help or adjunct, the metal would be of little avail. There is that ready adaptability to almost any—we might safely say to every—kind of construction, that facility for working it to which we have already alluded, in timber or wood, that there seems but little chance of its being superseded by either iron or steel. Certain it is that the civil engineer or the architect has not, as yet at all events, fallen back upon iron or steel for the construction of those adjuncts, scaffolding and the like, by which his larger and permanent structures made of those metals can be raised.

But the extensive and every-day-becoming-still-more-rapidly-extended use which iron and steel has met and meets with, for the larger structures of the civil engineer and the architect, and which in so far lessens the demand for timber, has in no degree been touched in connection with the wide field occupied by domestic houses, and that field nearly as wide and varied in its characteristics taken up by the structures required for our industrial works—our factories, mills, and workshops. Although iron, in the larger examples of the last-named varieties of constructions, is used to a comparatively large extent in the form of beams to span wide distances, or carry great weights, wood or timber is the material universally and exclusively used. In floors, partitions, and roofs, timber in large bulk is required daily; and for the interior fittings—as doors, windows, and the like—it is impossible, under our present exigencies of construction, to dispense with it. To its various uses in a large or bulky way, here named, it is scarcely necessary to add that of the shipbuilder. And although here also, as in the work of the engineer, iron and steel are fast and to a large extent superseding timber, it will be years before, if ever, timber gives way wholly to metal in the construction of the ordinary ships of commerce or the boats of the fisherman.

Nor does the demand for a regular and a large supply of timber stop here. For we have still to take note of the extensive field for its use in the thousand-and-one forms and fittings which our modern

civilisation demands. Nor is this demand likely to be reduced. On the contrary, we may say with safety that as yet we have only touched the outer fringe, so to call it, of the supply of timber. Hitherto but a few varieties of "woods" have been used for interior fittings of our houses, and of the various forms required by different trades and callings We are only beginning to discover the wide varieties which the forests of tropical and colonial countries afford—varieties which offer characteristics of the true value of which we have as yet but comparatively little knowledge.

The field, then, for the employment of timber—although, as we have seen, to a considerable extent narrowed by the increased use of iron and steel for a certain, although but a limited, class of structures remains practically as wide as ever. Taking, indeed, into consideration the marvellous development of our industrial processes and operations, and the wide variety of appliances which those processes and operations demand, and for which wood in one or other of its varieties is alone used, we may say that the field for the employment of timber is practically wider than ever it has before been.

Importance of a Knowledge of Timber to the Carpenter, Joiner, and Cabinet Maker.

The general subject, then, is one of great importance; and in considering those points it will be found that much information of a more than usually practically interesting character will be conveyed. We conceive it to be of the first importance that those engaged in the disposal, the use, and the treatment of any material used in the industrial arts should have as wide and as deep an acquaintance with all the characteristics of that material and of all points connected with it as can possibly be acquired. Of what a man deals with in his daily work, it is in brief impossible that he can know too much. What can be known it is his duty to know. And this holds as true of the timber dealer, who sells, as of the carpenter, the joiner, and the cabinet maker, who use the wide varieties of timber and of woods required in their daily work. But there is a difference between what a man knows in connection with his calling, and what can or could be known. He may know all that which is within his reach, but there may be much that—anxious as he may be to know it—does not lie within the range of that reach. This is perhaps specially true of the subject of a material of timber or wood. Other departments of constructive or technical knowledge have for one reason or another been again and again treated of in papers, in periodicals, or in special volumes; but timber has been to a very large—indeed, to a special—extent quite an exception to this. Much of what has been made

known as the result of observation, research, or experiment in connection with timber and woods, has been, as a rule, published in journals or papers which, strictly scientific or special, are not in any sense popular, certainly not easily within the reach of the general public interested practically in the subject Again, it is perhaps the actual fact—at all events it is not far wide of this—that the best papers written on the subject embodying information of the most practical character have been issued in foreign journals or published in foreign languages. Taken altogether, however, it may be said that the widespread character of the information—no less than the peculiar form in which it has been made public—places it in that position which makes it a difficult matter even for those possessed of facilities or of money to obtain it. Much more will this be the truth in the case of a vast number of those engaged in the daily work of our industrial calling.

It is our purpose, then, to place within the limits of the present series of paragraphs as wide a variety of information on the subject of timber and woods as our all too narrow limits will admit of. We use the term timber and woods here for a specific purpose. Popularly they are considered to be synonymous, or to be convertible terms. Strictly speaking, this is correct; for a piece of timber is a piece of wood, and the converse of this is equally true. Practically, however, the term "timber" is applied to pieces of large bulk, such as are employed by the "carpenter," for example; the term "wood" or woods to the smaller pieces used by the joiner and the cabinet maker.

Classes of Timber—Technical Names of Cut Timber.

The term timber is applied to all forest trees, once they are cut down. The trees which yield the timber used for constructive purposes are designated as timber or forest trees, to distinguish them from "fruit trees." But from this it must not by the young student be concluded that trees which bear fruit are not used to give supplies of wood. It is true that they are rarely used for the constructive purposes of the carpenter or the joiner—that is, they do not come within the class known as "timber" for heavy work. But as giving supplies of "wood" for the purposes of the cabinet maker they are of high value. Thus walnut-wood takes, as most readers know, a high position in the woods used by the cabinet maker. Apple and pear and cherry trees are also availed of for wood for various classes of work, although those named are perhaps more frequently used on the Continent than in this country. The timber obtained from forest trees, which are, as we have seen, the "timber" trees proper, and

sold for trade purposes, is classed into two divisions—first cut or squared timber, which is that usually sent from the countries abroad, such as America, from which our largest supplies of timber are obtained. This is known as "large timber," and is cut square in section, the side of the square being generally eighteen inches in length. Pieces which take the name of "balks" or "baulks" - generally the first of those two methods of spelling the term is used; a very popular name for this large timber is "log" are the largest pieces which can be cut of trees the length of which averages sixty feet. The section of balks or logs is square, the length of side varying from nine up to thirteen inches, the largest section being the most usually met with. "Large timber," the section of which we have seen to be also square, but with a much larger side, representing eighteen inches, is also generally designated as balks or logs. When forest or timber trees are cut up in this country—such as oak, fir, larch, etc.—their sale constitutes the business of a special trade--that of "round timber," sometimes designated also as "home timber," to distinguish it from foreign. In this the trees are not at first cut up square, but are sold in their natural form—namely, the round trunks or boles of the tree, the small branches being cut off; those being used for various purposes, according to size—the smallest for making charcoal, or sold to glass-blowers or manufacturing chemists for firing certain kinds of furnaces. Round timber, when the trees are of small or comparatively small timber, is used for a wide variety of purposes—as for "props" in coal pits, to prop up or support the roofs of the galleries and cuttings. Large-sized trees, such as oak, though sold in the "round," are cut up either as square or into planks, etc.

When timber is cut up for the purposes of the "joiner" it is known generally by the name of "deal," and is talked of as "wood"—the term "timber" being employed to designate large pieces. For the carpenter square timber or logs or balks are cut up generally into two, thus giving two "beams" of which the depth is greater than the width or thickness.

Technical Names of Cut Timber.

Deals are usually classified as of two kinds—"white deal" and "yellow deal." White deals are those without "resin," and therefore display no "humour," as the streaky veins which are met with in resinous timber are called; the surface of white deals is therefore of a uniform dead colour. White deals, having no resin in them, are easily worked or tooled by the joiner, planed, tongued or grooved, etc. They are generally used for inside finishing of houses, although

of late years "yellow and red pine deals," which still retain their resin, and in consequence have what is called "grain" or "humour," and when wrought and simply varnished give a pleasing characteristic to the doors, skirting boards, etc., which are made from them, have been much used for interior work. Yellow deals are more costly than white, and are much stronger, and in virtue of the resin which they contain last longer, and are therefore generally used for work exposed to the weather. Deals are usually described, according to the place they come from, as "Dantzic," "Memel," "Riga," or "Christiania," the countries in the north of Europe being our chief sources of supply. These timbers are generally classed as "Baltic"; but there is a difference between those we last named worth noticing: thus, "Riga" timber is of a better quality than "Memel," and is therefore better adapted for work exposed to the weather, "Memel" being best for internal work. "Dantzic" is very free from knots, and works freely. "Christiania" is well fitted for roof covering. "Dram" or "Drontheim" is a timber of inferior quality which comes from Norway.

American deals are usually known as "American pine." "Spruce deals" are obtained from the white fir of Norway; they have no resin. "Slab deals" are deals cut from the outside of balks or logs, and are of poor and varying quality and thickness. Deals are again distinguished by their width, thus giving them their distinctive names. Deals from eleven to twelve inches are termed "planks," although the term has sometimes a wider signification, being applied to all kinds of timber excepting fir, varying from $4\frac{1}{2}$ in. to 4 in. thick. The deal proper is 9 in. wide, and "battens" are deals from 2 to 7 in., usually 6 in., in breadth. They are frequently cut from deals, a deal being cut in two, giving thus a breadth of $4\frac{1}{2}$ in. to the batten. Deals are usually 3 in. in thickness, battens from $\frac{5}{8}$ in. to 2 in. The term "stuff" is in frequent use, and is meant to signify all pieces of work used in joinery, as distinguished from the larger pieces used in carpentry. The term "board" is of a wide signification, like that of "stuff," as it embraces all flat pieces of wood, although more specifically it applies to stuff over $4\frac{1}{2}$ in. in width, and under $2\frac{1}{2}$ in. in thickness. When boards are thicker at one edge than another, they are termed "feather-edged" boards, and are sometimes known as "clap-boards." Being used for the outside covering of sheds, where they overlap one another to be weather-tight, from this they are also sometimes named "weather-boards." Deals proper are cut into boards of varying thicknesses, and according to the number of boards cut from the deal they are known as "three-cut stuff," etc. Flooring-boards are usually $1\frac{1}{4}$ in. thick, two being

cut from a deal $2\frac{1}{2}$ in. thick, this being the thickness of a large proportion of the deals imported. Where a 3-in.-thick deal is split into two boards, $1\frac{1}{4}$ in. thick, a $\frac{1}{2}$-inch-thick board is also obtained, which is technically known as an "off-cut." When a $1\frac{1}{4}$-in. board is cut in two the two boards obtained are known as "slit" deals.

Characteristics of Forest or Timber Trees.

All forest or timber trees differ in appearance one from the other by an aspect peculiar to each of their kinds. The form of their trunk is generally conical—that is to say, of a diameter a little greater near the root than towards the top. The summits or tops of these trees are formed of the prolongation of the trunk divided into several principal branches; each of these branches is divided also into secondary branches, and the latter throw out boughs or little branches, to which the scattered leaves are attached by stems or petioles more or less delicate. At the first glance one might believe that the scattered leaves appear by chance; but a regular and constant order in each kind presides over their distribution. In cutting a tree perpendicularly to the length of its trunk, we see that it is composed of three parts easy to be distinguished: the bark which envelops it, the sap which occupies the centre, and the ligneous substance which is found circulating between the two first.

Structure and Physical Characteristics of Forest or Timber Trees.

Before entering upon the consideration of the general characteristics of timber as a constructive material, it may be well to examine briefly the tree itself before it is reduced to the state of timber. The *trunk* of the tree is composed of bark or exterior skin, the *sap-wood* immediately beneath the bark, and the *heart* of the trunk or interior hard wood, which possesses the greatest solidity of the three parts. It is this last portion that we use for building purposes; the sap-wood contains too much sappy organic matter to possess strength enough for use in construction; while the bark is without strength and solidity. The substance itself of a tree is composed of a "vascular" structure, which is common to all the plants used in building; the entire plant is made of a multitude of microscopic cells, and a knowledge of these cells, their disposition in the wood, and their compactness, etc., give the timber worker a clue to the general properties of the timber. Among vascular plants some are known as "exogenous," or those whose growth proceeds outwards (generally in rings which occur yearly, and thus by counting the rings in most trees their age can be calculated); and the others are called "endogenous," as their mode of growth is the opposite to the last

class—taking place from within, the outer part being the oldest in the trunk. Fig. 92 is a rough sketch of a cross section of the first class, and fig. 91 a cross section of the second class, of vascular plants. All timber trees used in this country belong to the exogenous class. As the growth in such trees takes place in the centre, and proceeds from a multitude of cells there situated, these latter, when they have performed their office—have lived their life—dry up and form a soft substance in the centre, called the pith. The cells are of very different shapes, sizes, and properties in different trees; and, indeed, the ultimate properties of any tree depend almost wholly upon those of the individual cells of which the tree is composed. When these cells are united together, and lie close to each other, the mass is called cellular tissue; while if the juice contained in these cells or sacs becomes dried up and leaves empty cells instead of filled cells, the mass is known as vascular tissue. The woody part of a tree is composed of vascular tissue. Immediately around the pith of the

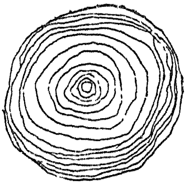

Fig. 91.

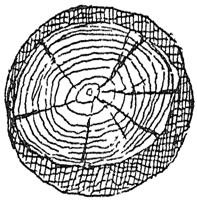

Fig. 92.

trunk lies the "medullary sheath," composed of vascular tissue, of which the vessels (or empty cells) have spiral walls, the fibres of which can be unrolled. The "woody tissue" is next this medullary sheath. The wood nearest the pith is the hardest, and called the "heart-wood"; that nearest the bark is the most tender, and termed the "alburnum." The latter, again, is surrounded by a layer termed the "cambium," or more commonly the sap of the tree. All these layers are pierced by a series of plates reaching from the centre to the circumference, called the "medullary rays," and form the well-known *silver grain* or veins or humour of the tree.

The heart-wood is the most valuable part of the trunk, and the greater the proportion of this the more suited is the tree for industrial purposes. Different trees exhibit different proportions of sap-wood and heart-wood. The increase of the zones of an exogenous tree does not take place uniformly each year, climate and season having a great influence upon the growth. Moreover, there is frequently seen an irregularity in the growth, one side of a zone or ring being

thicker than another. These rings are not always well-defined, as seen in a section of the trunk; so that it is frequently (especially in the case of an old tree) a matter of uncertainty to determine the age of a tree by counting the yearly rings of growth.

For general purposes, and where great compression is to be resisted, the greater the proportion of hard to the soft portion of the wood the more valuable is the timber; for cutting up into planks, however, wood having a moderate development of hard part is most useful, as not being liable to cracks and warping.

From the word *liber* is derived the French word *livre* (a book), because the ancients wrote upon the leaves of which this is composed. It has been proved that there forms between the liber and the sap-wood another layer, which is the continuation of both; the material of this generating layer has received the name of *cambium*. It is developed in spring and autumn. Its inner part changes insensibly into sapwood, and the other changes into liber. The liber never becomes wood; it is continually driven back by this mode of growth of the tree, and forms the bark, which tears and exfoliates externally, because it dries up, and the leaves of the liber cannot, in growing old, extend in proportion to the increase of the circumference of the tree. In proportion as new layers of sap-wood are produced, they form new coverings, the traces of which we observe on the transverse cutting of the trees. These layers are numerous in proportion to the age of the trees. Many authors maintain that it is a mistake to believe that the number of years of a tree may be counted by its ligneous layers. Nevertheless, the opinion most generally admitted, and which appears to be founded on recent observations, is that the number of concentric ligneous layers marks that of the years of the trees. We may remark that, although each year sees the formation of a ligneous layer of sap-wood, and a layer of sap-wood transformed into perfect wood, it requires, nevertheless, several years for the transformation to be accomplished, since the sap-wood always consists of several yearly layers. We can scarcely calculate the life of a tree. We believe that the oak may live more than three hundred years. The ancient forests furnish proofs of this, if we refer to the number of ligneous layers which we count in their enormous trunks. In oak wood the annual layers are from three to four millimetres in thickness; each layer is formed of a hard and solid ligneous substance in the perfect wood; another substance distributed among these layers and joining them is spongy, and forms a sort of network, which is only one millimetre thick. The more of these layers the trees contain, the older they are; and the more of them found in the same diameter,

the harder and heavier is their wood. We remark that in extremely hard woods, as in very soft woods, the circles of yearly layers are scarcely visible. We do not see them in ebony and in some island woods, nor in the poplar and some other white woods of our climates.

Influence of the Soil upon the Physical Characteristics of Trees.

The thickness and good growth of trees are not always in the same species infallible signs of the good quality of their wood. The connection of age with the size of a tree, the nature and the situation of the soil in which it has grown, should also be examined, to judge of the quality of the woods which cultivation would furnish. In general, marshy soils only bear trees the wood of which is light and spongy in comparison with that of trees of the same kind grown in good high lands. The water, too abundant in the low and clayey soils, where the roots are nearly always under water, does not give to the sap the qualities necessary to constitute good wood. The trees grown in soils of this kind, which are not suitable for their species, are useless for carpentry work. Oak wood, for example, grown in damp soil is more suitable for joiner work than for carpentry, because it has less strength and stiffness, is softer and easier to work than oak wood grown on a dry and high soil; it is less liable to split and crack when it is used only for objects of small size.

Damp or moist or watery soils are only suitable for alder trees, poplars, and willows. Some other kinds thrive in cold or simply damp soil; but the species of oak, elm, and chestnut thrive only in dry soils composed of good earth, retaining after rain only the necessary amount of moisture without stagnation to support good vegetation. It is the same with resinous trees, which do not always thrive in the soils suitable for the other kinds, and, above all, in marshy soils. In general, sandy soils suit them best, and some kinds do particularly well in the neighbourhood of the sea; such is the maritime pine, as valuable for its resinous products as for the quality of its wood. Lastly, in poor and stony ground, which opposes the easy progress of the roots, and cannot furnish them with the nourishment suitable for their species, the trees attain only a slight growth; they shoot up slowly and only produce rough wood, often knotty and stunted and difficult to work. They can only serve for coarse work unless they are suitable, from their colour, their hardness, and the peculiarities which they present, for veneering furniture, or for making some ornamental objects, like mahogany and some parts of the old walnut trees. The best signs of the good quality of a tree are the beauty of bark and the slight thickness of its sap-wood. This last sign shows that the substantial quality of the soil has

shortened the time of the transformation of the sap-wood into perfect wood. We might, to a certain extent, by scrutinising this soil, judge of the quality of the wood of the trees which it has produced.

Influence of Atmospheric Changes on the Quality of Timber or Forest Trees.

We have remarked that, at the same age, the trees grown on the outskirts of a wood are larger, healthier, and of better quality than those grown in the interior, which may be attributed to their having enjoyed more of the influence of the air. The trees of the glades have a superiority of shape, of thickness, and of quality over those which grow in the bushy parts of the forests. We observe also that certain exposures have, as much from the action of the sun as from the winds and the forms of the surrounding soils, an influence upon the growth of the trees and the perfection of their wood. Trees grown on an eastern and southern exposure have often hard and good wood; but they are full of branches, sometimes tortuous, and for this reason it is difficult to get from them good pieces for carpenter-work. On a northern exposure the trees are finer and more straight; their wood is much less hard. On the west the trees, beaten by the wind, are bent and often distorted, their wood is often twisted.

We may remark especially, on the maritime coasts which have this exposure, that the trees suffer, their heads are bent, their summits are in the form of an inclined plane in consequence of the pressure of the wind.

Importance of a Knowledge of the Practical Points connected with Timber.

Many practical men rest satisfied with what may be called the rule-of-thumb method of determining the quality of the timbers and woods they use in their respective trades; or, to be more precise, depend upon their eye as the best means of judging—as, for example, as expressed in this often-repeated phrase, "I know a good bit of timber when I see it"; or this other, as expressive of confidence in their own knowledge, if not quite so grammatical, "I know by the looks of it, what kind of timber I have to deal with." While no doubt a long experience in the dealing with and the working of timber gives a practical man a ready facility in judging of its quality, and while some men possess what might be called quite a natural faculty in this direction—intuitively, so to say, telling which timber is good or bad, or but of medium quality—still, at the best, time is an important factor in the calculation, and the young, or the comparatively young, practitioner cannot possibly expect to know as much about timber as one who has been handling and working with it for

a period of practice very much exceeding the duration of that of the younger man. And yet the man young to the business is all the same called upon to do work and to decide upon points just as important in their nature as those with which the older practitioner has to deal, who may be able by a mere glance at and handling of a piece of timber to tell at once its value as a constructive material. The young practitioner, if desirous to excel in his calling, while taking every pains to learn as much as possible from his daily work, and to avail himself of the wider experience of such older men as those with whom he comes in working contact, is nevertheless forced, so to say, to gain as much knowledge as he can from a close and careful study of the general subject of timber. And although this has for the most part to be gone into with the aid of books, or the practical papers read before our leading societies, the practical student must not, as some do, detract from the value of the knowledge so gained simply for the reason that it has been gained through the medium of books. The indifference to, the covert if not open sneering at, book knowledge, which some practical men manifest and practise, is, if they will only look at it, just as unwise from their practical point of view as it is in reality altogether erroneous, arising as it does from an altogether erroneous conception of how the case stands. Those who object to books or scientific papers as a medium of gaining knowledge, useful to them in their daily work, proceed upon the assumption that the books or papers are made up of matter purely fanciful, conjectural, or theoretical, ignoring all practical points of daily utility. While, no doubt, both books and papers are in some instances written by those who have little practical knowledge of the subject of which they treat, still, a book or paper with any pretensions to value will contain something which will be all the better for one to know, rather than be ignorant of. But there are both books and papers numerous enough to afford a wide range of choice, written by thoroughly practical men, who know well from experience in working all the essential points of their subject. Their books and papers are, in fact, records of their own experience, or of that of others as practical as themselves, and which they would not quote or give unless their own knowledge, their own practical experience, told them that such information was practically valuable. What they write is of precisely the same practical character as the information which one picks up by a "good business talk" with an old experienced workfellow; the only difference being this—that the one gives you practical knowledge through the medium of his talk, the other through that of a practical book If a man tells you what is a truth or fact in technical work—such, for example, as that timber obtained

from an oak tree grown in a certain soil and under certain conditions in relation to other trees is not of such good quality as that grown in another soil and under other conditions; or, for example, as this, that the timber of a tree is better in quality when the growth has been slow and gradual in rather a poor soil, than when in a too rich one it has been quicker,—if these facts, and all the facts or truths named, are moreover backed up by the reasons why they exist, surely facts are not less valuable because they are communicated to you through the pages of a book, than if they were told to you by a fellow-workman in a quiet chat. Some who object to books or papers as a medium for obtaining knowledge, oddly and inconsistently enough have no objection to lectures. Yet, what are lectures but spoken books? or what are books but, so to say, recorded—that is, printed—lectures? We have insisted somewhat on this point, as it is one of much greater practical importance to those engaged in technical or industrial work than many seem to conclude that it is. As we have already said, if practical knowledge is only considered valuable because it has been gained by practical experience, then time must be an important factor in the calculation, and, the process of gaining knowledge requiring time, a man may have to grow grey-haired before he becomes one of ripe and full experience. And this is just what we find in actual working life. And such men assuredly could not have been in any way worse off—common-sense tells us that they would have been much better—had they got some facts of their experience from books and papers, which themselves are but the records of the experience of other men as practical as themselves, at an earlier period of their lives. And although it is perfectly true that in all classes of work in which manipulative skill is required no books can possibly give the facility to do the work accurately; still, on the other hand, there are an abundance of facts and truths of great practical value to the workers in such callings, which never could be learned or acquired by mere manipulative practice or skill, even if they were exercised for a lifetime. We would, therefore, urge upon the young student the absolute necessity that he should gain as full and accurate a knowledge of all the facts connected with trees and timber as he can obtain from books of authority. And the older practitioners will be none the worse, but all the better, if they do the same.

Practical Points connected with Timber.

In the course of the paragraphs already given, the young student has had various points connected with timber placed before him. Some of these he may consider as in no way greatly concerning him,

as he is what he calls himself a practical man, desirous to deal only with facts, and having no great liking, if any, for theory, with which books, as he says, but too often and only deal. On the relation which books have to the practical man we have in preceding paragraph presented certain suggestive points to a reader of this class—and which could have been greatly, and as we venture to think usefully, added to, had space been at our disposal. And as regards facts as againstt heory only, we might—if this same necessity of space was granted us—show that the prejudices which many practical men bear towards theory are but ill founded, and that often certain points said to be theoretical only are in truth purely practical. Hence, while, as we have said, some of our more youthful and inexperienced readers may decide that some of what has been given in preceding paragraphs does not concern them, a closer study even of those points will, however, make very clear that they are worth knowing, because they are in their outcome practical, although at first sight they may not seem to be so. For example, the remarks as to the soil in which the trees from which timber for constructive purposes is taken having an influence upon the quality of the timber, may to some readers seem to be anything but practical to them. For, as they may remark, what is the growth of a timber tree to us?—that is a detail over which we have no control. We have simply to take the timber as it is sold to us; we may not—generally, indeed, do not—know even where the tree was grown. But the case may be different in some parts of one's experience. *Home-grown* timber is sold and used to a much greater extent than one may be disposed to believe, and one may be called upon, if not to select, at least to give an opinion as to the likely value of the timber which the tree or trees will yield. And as every reader will possess—we hope he will possess—the legitimate ambition to "get on in life," we should not like to think of him being called upon to give an opinion when he found his knowledge—or rather the lack of it—an obstacle in the way of his giving an honest opinion of value to his employer. But even should such circumstance never turn up in the experience of his life—when he is informed of the fact that some peculiarities which he meets with in timber can only be explained by taking into consideration the circumstances attendant upon the growth of the trees from which it was obtained—such a reader will come—as we trust he will—to see that he cannot possibly have too much information on the subject, cannot know too many facts connected with timber, as even in the most unlikely cases—as such may seem to him to be—he never knows when occasions may turn up when such knowledge may prove of direct and incontestable value. It should

never be forgotten by the young technical student that when knowledge is gained he is just so much the richer; that once acquired, it need not be lost; that the carrying it about with him involves no labour, incurs no fatigue, and it is ready for use wherever it is required, and often required, moreover, at times the most unexpected, and these when it is most valuable Not only does the soil influence the character of the timber which a tree yields—oak, for example, grown in an undressed clay soil possessing too much moisture, but grown in a rich loamy soil growing so quickly that the wood is soft, while it possesses the same bad characteristic of a tree grown in a clayey soil, namely, too much sappy moisture,—not only is the soil an element in the question of the growth, as exercising an influence upon the quality of the timber which it yields, but the mere position of the tree or trees has an influence also upon this. It is obvious, for example, that the sun exercises a powerful influence upon all vegetation. If exerted more frequently upon one tree than upon another, that which gets the most sun-heat will have less sap than the one which gets the least. The closer the trees grow together, the less sun-heat do the inner ones receive. Each tree in this respect differs from its neighbour as its position differs; hence the timber will be different in all, those standing at the outside of the plantation growing the best, other circumstances being equal. Trees growing too thickly spring up too quickly, and become lanky and soft in the interior. Oak trees standing alone, or nearly alone, exposed on all sides to the weather, are of slow growth, but give the hardest, strongest, and most durable of timber. From this the reason will be seen why oak trees grown in the north, having less sun and more of what is called a "trying climate," give better timber than those trees grown in the softer climate of the south of the kingdom. As a rule, then, the best timber is got from the trees which have been the longest in growing, and where the soil is dry.

The timber obtained from a single tree—and the remark, be it noted, applies equally to a balk or log of timber, which is only a tree cut down and squared—is not of equal value throughout. In the case of a tree, its mere position in the soil creates a difference in the quality or character of the timber in different parts. Thus the side nearest to or facing the north point of the compass is found to give the hardest and most durable timber, its concentric rings or layers lying closest together, giving a more compact timber, and this from the fact that there is less moisture present in it, this being forced or rather drawn out towards the south side of the tree, which receives the most sap, and is the softer, and that having its layers or concentric rings wider apart. This it is which changes the position

of the centre so called, or heart of the tree, which, as a rule, is rarely found in the exact centre of the circle of the tree. The presence of knots on a tree or balk greatly influences the character of the timber. The strongest timber is that in which the grain is the longest and the least interrupted, and as all knots interrupt the continuity of the grain, their presence weakens the timber. And knots are bad in another sense, inasmuch, as every joiner knows, a knot falling out will render an otherwise good plank or deal useless for any purpose in which an unbroken surface is required All knots are disagreeable things to meet with in working up timber All knots, as perhaps even the youngest of our readers will know, are the remnants, so to call them, of the branches which grow at those parts of the tree at which the knots are found. And knots are not always found, or make themselves manifest, at the outside or external surface of a tree when cut down and trimmed of its branches, or of a balk or log. For a branch may fall off from decay, or be broken off by the wind, or by design, at a period in the growth of the tree long before that growth is completed. And the end or part where the branch grew, exposed by the breaking off of it, is not pushed outwards, as some may suppose, by the continued growth of the tree; but the new growth the rather covers up and conceals the knot or remnant of the branch broken or fallen off Hence it is impossible to tell how much a balk or log not cut up is "degraded," so to say, by knots Cutting up into deals may show the presence of knots not at all visible on the exterior before being cut up. This and the other facts, that parts of the interior of the balk or log may be rotten, or so far decayed, and that the timber is weakened by shakes or disturbances of the grain of the wood, explains the reason why there is so much waste in cutting up a balk or log into deals. Knots, however, seem to fulfil a certain useful office in timber trees or in balks, as we find that timber which is knotty is freer from shakes or looseness or disturbance of the grain at the core or heart of the tree, than when the knots are absent, this office being likened to that which screw-bolts and nuts fulfil in binding constructive parts together. Knots have, so to say, their own peculiar locale in a tree, being found in greatest number nearest the centre or heart. The greater the distance from the centre, the fewer the knots. This may be explained by supposing that, in the earliest stages of the tree growth, it has not the power to cover up or push out the root or remnant of the broken or rotted-off branch, which, as we have seen, is the cause of knots. One reason why American timber is held in such repute is that it is remarkably free from knots. And, as a rule, the more free wood is from knots, more especially those which are dead and

loose in their seats, so to call their locale, these being in more ways than one the plague of the wood worker, the more valuable it is. The worst of all kinds of knots is the knot in which the bark of the root or remnant of the broken-off branch remains, and is embedded in the tree. This bark becomes soft or shrunk, and thus loosens the solid part of the knot, which thus drops out, leaving an awkward hole. Knots of this kind are known by heavy or thick rings round them, the dark part indicating the bark

The qualities wished for in timber are, first, density or compactness or solidity, and consequent hardness of the fibres or of the grain, as the technical expression is. The second quality is durability; the third quality is weight or heaviness; and the last, but not by any means the least, for many constructive purposes, is strength. These qualities are not all met with in the due proportion desired in all timber; in some qualities one or other is very weak; in some timbers they are all weak. The strongest timber is found in the region of a tree midway between the sap-wood and the heart or core of the tree. The weakest part of the timber is that nearest to or encircling the core or heart of the tree. The core or heart itself is weaker than other parts exterior to it, and the part next to the bark is the weakest of all. Strength and heaviness or gravity generally —but not always—go together. But all parts of the same tree or balk are not equally heavy, the heaviest part of the timber being that nearest the root or bole. The part nearest the root is generally the coarsest in the grain. When a tree is in progress of growth, the central parts are the strongest; but when growth is completed, the longer the tree stands the more does the value of the timber deteriorate—as after maturity decay begins to set in at the oldest parts, or those nearest the centre. And in like measure the same applies to balks, or logs: the older they are the more likely are they to be deteriorated in value, till timber, indeed, brings less money the second year than was its value in the first; and it is less valuable in the second than in the third. But when the timber is thoroughly seasoned, then this rule does not apply. It is scarcely possible to season thoroughly timber in the balk or log; but the process of seasoning may be applied with success to cut timber—that is, deals and planks. Timber in the balk does not from its external appearance give any trustworthy indications of the value of the deals which may be cut out of it. One has to saw a balk or log up before he can pronounce with certainty as to its working value. Balks or logs are frequently disfigured by splits or fissures; unless of great extent, or very pronounced in character, they will not affect materially the strength of a balk if this is used as a beam. When a balk is sawn into two, a

weakness or softness at the core will often show itself, the existence of which could not have been predicted from any external appearance. When two girders are sawn or made out of a balk, the girders should at once be trussed, this after shrinking from the drying, tightening up the trusses. In place of using a beam of one thickness it is a good plan to saw it up longitudinally in the middle, and turning the insides out, make a flitched beam of the two. This will enable the wood to get dried and seasoned, and may put a stop to the softening or decay of the heart-wood which may then begin to set in. After timber has been cut up into deals, and even after they have been what is called well seasoned, the troubles connected with it may be said to begin for the worker in this material. For although deals and the parts made of them do not alter in the sense of their length, they alter most materially in that of their breadth or surface. For the boards shrink or contract in width; they warp or cast or become twisted and bent into the most curious and to the artificer most perplexing of ways. The shrinking of pieces secured with nails, etc., gives rise to the most awkward of rents and splits, of which the fittings of not a few houses display some too prominent examples. Woods have different capacities for shrinking or contracting, but the best, or those least given to it, are often bad enough in their effects. Warping, bending, or casting, is also an awkward characteristic in woods; but may, to a large extent, be prevented by "lasting" the boards or deals, this operation being the planing off of all sap-wood from the edges of the boards.

Varieties of Timber.

American oak is largely used, but it is not so good as the oak grown in the northern parts of Europe. Oak timber is at its best when the tree from which it has been cut has attained maturity; the grain should be straight, and the heavier the timber is the better is its quality. Oak is most valuable when used for parts exposed to the weather. The weight of a cubic foot of English oak is 50 lb., American 47 lb., Baltic 46 lb.

Fir or pine is the most extensively used of all the timbers. The principal sources from which it is obtained are the vast forests of Northern Europe and America. The species known as the *Pinus sylvestris*, which grows largely in Northern Europe, yields the "yellow" deal; the Norway spruce, or *Pinus albus*, yields the "white" deal. This timber has a fine grain, is easily worked, and the surface can be brought to a good polish. The weight of a cubic foot of Dantzic fir is 35 lb., of Memel fir 38 lb., red pine 40 lb., yellow pine 33 lb. The *Pinus resinosa* is the tree which produces the

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"American pitch pine," which is the most valuable of the American tree firs. It is very close in the grain, is resinous, generally free from knots and streaks, and is durable; its weight per cubic foot is 40 lb. to 42 lb. The white pine of America is obtained from the *Pinus strobus*; it is chiefly used for joiner's work, although in many districts its use for heavy or carpenter's work is largely on the increase, and is by many preferred to Baltic timber. The weight per cubic foot is 28 lb. to 30 lb.

Elm—*Ulmus campestris*—is a durable timber, especially in cases where it is kept continually wet, as in piling, planking for foundations, etc. It is generally coarse-grained and porous; it does not work easily with the tools, being cohesive in its nature; it is not liable to split under the strain of nails, bolts, etc. The weight per cubic foot is 39 lb.

Beech is of two kinds, the black and the white; the black is generally considered the most durable of the two, it is also tougher. Like the elm, it is very durable when exposed continually to wet, although it decays rapidly in damp, or where exposed alternately to wetness and dryness. Beech is much used by the cabinet maker for furniture purposes; a variety known as the silver beech, recently introduced, is very beautiful when made into articles of furniture. The weight per cubic foot is 50 lb.

Ash is a tough and elastic timber, used chiefly for mill and machine work. It is durable if kept dry, but soon decays if subjected to alternation of dryness and damp or wet. The weight of a cubic foot is 50 lb.

Sycamore is a close-grained timber, is easily worked, and can be brought to a fine polish; its colour is a whitish yellow. The weight per cubic foot is 37 lb. The sycamore, in some parts of the country, is often called the "plane," but the true plane is a distinct species. It is similar in appearance and quality to the beech, it works easily, and is very durable in water. The weight of a cubic foot is 45 lb.

Poplar, of which there are five species in this country, grows abundantly. The trees are very subject to decay; the timber is used for various purposes, where the scantlings are small. The average weight of poplar per cubic foot is 32 lb.

Mahogany is of two kinds, Spanish mahogany and Honduras. The weight per cubic foot of the former is 55 lb., of the latter 40 lb.

Alder is a timber eminently adapted for foundations and piling purposes, being exceedingly durable in water. The weight per cubic foot is 35 lb. to 45 or 50 lb.

Chestnut is a valuable timber, closely resembling English oak in nearly every respect; but it is easier to work, and is tougher, and

does not discolour at the parts exposed to the action of iron. Its weight per cubic foot is 35 lb.

Walnut and rosewood are chiefly used for cabinet-making purposes. The weight per cubic foot of walnut is 35 lb., of rosewood 44 lb.

Teak, an Indian timber, although light and porous, is so strong and durable that it exceeds oak in these respects Its weight, per cubic foot, is 41 lb.

Larch is a very durable timber, and is used extensively for railway sleepers; but is well adapted for building work. The weight per cubic foot is 30 lb. to 45 lb.

Decay in Timber.

Decay in timber is caused chiefly by the presence of the natural juices or "sap," or from moisture which it may receive from various sources. The tendency to decay is greatly modified by the natural properties of the timber itself, and by the kind or quality of the sap. Timbers vary greatly in their natural properties, according to the physical, or we should perhaps say the mechanical construction of the fibre, and partly to the nature of the sap. The construction of the fibre includes not only its form, but its substance also. This point is important, inasmuch as the evaporation of the watery portion of the sap of the wood, which is vitally necessary, is either facilitated or retarded, according as the fibre is open and spongy, or close and compact. And again, in wood where the fibre is close and compact, such as oak, beech, etc., the proportion of sap to fibre is much less than in the open and spongy woods, such as fir, willow, etc. But although the porosity of wood is important, as being the medium of evaporation, the nature of the sap is a point of greater importance for the following reasons. When a tree is cut down, it is charged with that quantity of natural moisture which has been necessary for its vegetable existence. Now, the second cause of the difference in the properties of wood is the nature of the sap which has nourished it whilst growing. It is scarcely necessary to state that the sap of all trees is not alike. This difference is caused by the various proportions of different chemical substances which enter into its composition. For instance, the sap of some trees is more or less resinous, as that of the pine; gallic or astringent, as that of the oak; or mucilaginous, as that of the cherry tree; and according to the increased proportion of these substances which the sap contains, there is less liability to rapid decay; whilst, on the contrary, the more water the sap contains in its natural state, the less durable is the wood when deprived of vegetable life.

The decay of wood of all kinds dates from the time that its vegetable life has been destroyed by cutting down. From that moment the work of decomposition begins, and is expedited or retarded according to the nature of the wood, and the length of time that may elapse before the watery portion of its sap is evaporated. If, then, such moisture is allowed to remain, decay soon becomes perceptible; but, on the contrary, if it be expelled, the process of decay is slow, and so gradual in its operations as to be imperceptible for centuries in some descriptions of wood,—and hence the necessity for using well-seasoned wood.

The chief cause of decay in wood is generally understood to be the fermentation of the nitrogenous substance contained in the sap, caused by the oxygen in the air acting upon the moisture of the wood.

Seasoning and Preservation of Cut Timber.

Timber thoroughly well seasoned implies that condition in which its good qualities will be preserved, so that in one sense the seasoning and preservation of timber may be taken as the same terms. But timber may be well seasoned, and yet we may place it in such unfavourable conditions that it loses the good properties it may possess, and begins to decay. The term "seasoning," therefore, may be accepted as indicating the process by which we give timber good qualities—that of "preservation" the process or means adopted by which we retain in it those properties.

Seasoning.—The oldest and most generally adopted method of "seasoning" timber is steeping or immersing it in water. This method is based upon the fact that, by placing the timber in water, the sap is washed out of the pores and the water takes its place, which, when the timber is afterwards exposed to the atmosphere, is much more easily and quickly expelled by evaporation from the timber than the sap in its ordinary or natural condition. To obtain the best results of this mode of seasoning in the quickest way, two things are essential: the water must be running water, and it must be as pure as possible. "Natural seasoning" is simply exposing the timber to the air, under sheds or otherwise piled up.

Preservation of Timber.—The most generally adopted mode of preserving timber after it has been, or is supposed to be, seasoned, is painting its outer surface. That this is effective only under certain circumstances we all know; for paint itself, under the action of the atmosphere, rapidly decays, exposing the timber to the action of the same. Coal tar is a good preservative. It is much more lasting when mixed with sharp river sand, which may either be mixed with

the tar and the mixture painted on, or the tar may first be put on, and the sand strewed or thrown or dashed over the surface while the tar is wet. It is best to use the two modes in conjunction—that is, putting a small quantity of sand in the tar in the first instance, and painting the surface, and finishing by strewing the sand over the whole. The same method of using sand may be adopted with ordinary paint. In preventing the attacks of fungi on wood, a paint made of 100 parts of flour of sulphur, 15 parts of linseed oil, and 67 of manganese, has been used with effect. A surface preservative is highly spoken of. It is made up as follows:—Linseed oil 15 parts, resin 15, tar 5, white lead 12, any colouring material 4, cement 6, oxide of iron, glue 2, hydrate of chalk, lard 15, litharge 2. The whole to be boiled and reduced to one-tenth of the original bulk, and applied hot. The carbonising or charring of timber, as in the case of the feet of posts, which are to be inserted in the ground, is a good method of preserving it. A process has been recently patented for charring the surfaces of joists, etc., used in building.

In Bethell's process of preserving timber, the heavy oil of tar, in which creosote is largely present, is employed. This strongly odorous substance coagulates the albuminous matter found in timber, and hardening it partly increases the strength of the woody fibre; and as the oils are insoluble, they cannot wash out of the timber. Further, their action is such that they effectually prevent worms from attacking it; they absorb the oxygen by which decay is promoted, and they also resinify the interior pores, preventing access of air, and are obnoxious to all fungi and animal parasites. From the colour and objectionable smell, however, which the oil imparts to the timber, the process is only available for outside work. The patented process is rather complicated, but for all ordinary purposes the plan of simply steeping the timber in the oil in a tank made for the purpose will be amply available The timber should be dried before it is put into the tank, in which it should be allowed to remain for twenty-four or thirty-six hours, according to circumstances. The oil should be made hot in a pan or small boiler. This process of immersion will be found very useful; but where it cannot be carried out, much of its advantage will be obtained by simply painting the surface of well-seasoned timber with the oil. This will make the timber last longer than if this painting be not done.

The Felling of Trees for Timber.

When used for building purposes, it is necessary that the trees,

at whatever period of the year they may be felled, should not be allowed to stand so long as to exceed their average period of growth. This is important, when we consider that timber allowed to be too old before it is cut is likely to have what is technically known as "star shakes." Star shakes in old timber are cracks in the wood, which radiate from the centre to the circumference of the tree, having their greatest width or extent of opening towards the centre of the tree, or that part where the timber is most valuable; whereas in young trees the star shakes, while radiating as above, have their widest opening at or towards the circumference of the tree, or at that point where the least valuable part of the wood is met with. This point bears, then, upon the value of the timber; but it also appears that the value is influenced by the season of the year at which the timber is felled. The best season would be that immediately preceding the period when the "sap" movements begin, in early springtime. Practically, however, the felling season should extend itself from the period when the sap movements or active vegetation cease in the autumn to the period before it begins in the spring.

As the sap movements in timber exercise a most important influence upon its value, it will be interesting here to glance briefly at a few points connected with them. The sap of trees—which is composed of oxygen, nitrogen, hydrogen, carbon, and sulphur, and which forms a considerable proportion of the bulk of the green or fresh wood—is, as may be supposed, a varying quality, and that according to the season. From the fact that the sap movements are most active in the spring months, it might be supposed that the amount or quantity of sap in trees would be greatest in spring. Accurate experiments show that this is not so, and that the greatest quantity is met with in the months of December and January. It gradually diminishes in the months of October, November, February, and March, next in April, May, August, and September, the minimum being in the months of July and August. Of course these general statements must be modified by circumstances, such as dry and wet seasons; but the rule, as a whole, stands as we have put it. After being cut down, the sap, as a rule, evaporates gradually; it is only in some cases that the sap is got rid of by its flowing or exuding from it, and this flowing out is greatly dependent upon the state in which the timber is after being felled; for if the bark is stripped, the flowing-out of the sap from the wood is much quicker than in cases where the bark is allowed to remain on. With bark stripped off, the weight of the sap gradually diminishes; but with the bark on, this fluctuates, moisture evidently being absorbed from the atmosphere by it.

Useful Rules in connection with Beams, Floors, Roofs.

Under this heading our space will not permit of our giving more than a few of the leading calculations respecting what may generally be called framing work. Of this the general principles have been already, under the division of this work on Carpentry, given in preceding paragraphs.

To find the dimensions of a strut or brace of fir, the length of which is given.—Multiply the length of the brace in feet by the square root of the length of the part of the rafter, supported by a brace; multiply by 0 8 the square root of the result. The quotient will be the depth in inches, and the depth multiplied by 0·6 will give the breadth or thickness of the strut or brace.

To find the depth of a flooring joist of fir, the thickness and length being given —Square the length of the joist in feet; divide this by the thickness, and multiply the cube root of the result by 2·2, which will give the depth.

To find the depth of a ceiling joist of fir, the length and thickness being given —Take the cube root of thickness in inches, and divide the length by it, and multiply by 0 64, which will give the depth in inches.

To find the thickness of a fir girder, where the bearing or distance between the walls and the depth are given.—Take the square of the bearing in feet; divide it by the cube of the depth in inches, and multiply the result by ·74, which will give the thickness.

To find the depth of a fir girder, the bearing and breadth or thickness being given.—Divide by the breadth in inches the square root of the bearing in feet, then multiply the cube root of the quotient by 4·2.

To find the thickness of a bridging or binding joist in fir, the bearing in feet or the length and the depth in inches being given.—Cube the depth in inches, and divide it by the square of the bearing in feet, and multiply the result by 40.

To find the depth in inches of a tie-beam of fir, in which the bearing in feet and the thickness in inches are given.—Take the cube root of the breadth in inches, and divide the bearing in feet by it, and multiply the result by 1·47.

To find the depth in inches of a principal rafter of fir for a king-post truss, the length in feet and thickness in inches being given.—Take the square of the length in feet, multiply it by the span in feet of the roof, then divide the result by the cube of the thickness in inches, and multiply the quotient by 096 and by 0 155 for the rafter of a queen-post truss, which will give the depth in inches.

For common rafters, of which the length in feet and thickness in inches are given.—Take the cube root of the thickness, and divide by it the length in feet; multiply the result by 0 72, the depth will be obtained.

To find the dimensions of a king-post in fir, the length in feet being given.—Multiply the length by the span of the roof in feet, and the result by 0·12, the quotient is the area in inches.

To find the dimensions of a queen-post in fir, the length being given —First find the length in feet of the tie-beam which the queen-post supports—generally one-third—then multiply this by the length of the queen-post in feet, and multiply the result by 0 27, which will give the area The depth of king-posts and queen posts should correspond to the thickness in inches of the tie-beam of the truss; so, this being a known dimension, the thickness of the posts will be found by dividing the areas found by the two last rules by this dimension.

To find the dimensions of purlins in fir, the length and the distance they are placed apart being given.—Cube the length, and multiply this by the distance apart; the fourth root of the result is the depth, which, multiplied by 0 6, gives the thickness.

END OF "THE CARPENTER."

THE JOINER.

Introduction.

THE material with which the joiner works, like that of the carpenter, is timber or wood. These terms are scarcely synonymous. Taken as separate or individual names, they in some measure indicate the difference which exists practically between the two classes of work, that of the carpenter and that of the joiner. When the term wood is used generally, it is intended to convey the idea of the kind or class of material obtained from trees, large or small as the case may be, and which as a constructive material is known to possess qualities very different from the other constructive materials known as stone or iron. But when we come to use the generic term wood, as applied to some definite kind of construction, we find that it assumes two branches, to one of which the term "wood" is still applied, to the other the term "timber." And it may be safely held that even in popular estimation the term "timber" or "timbers" conveys the idea of the material present in large masses, to which the names of "balks," "logs" or "beams" are applied; and the trade concerned in the working up of which is also popularly understood to be that of the carpenter. On the other hand, still keeping the distinct trade in view, when we talk of the generic name for the material as being used, we give the term "wood" or "woods," and conceive of its use in connection with the work of the joiner. And joiner's work, we all know, deals with the material in comparatively and actually small masses or pieces, the work done with these giving a very wide array of names.

The Distinction practically made between Carpenter's and Joiner's Work.

The distinction above glanced at in practice constitutes the difference between the work of the carpenter and the joiner. The carpenter deals with the material in the form of long and bulky pieces, and out of them arranges certain large structures, forming the joints and piecing or placing them together, in order to make—keeping in

view house building or construction only—the floors, partitions and roofs. These may in one sense be called the external work of the structure, but more correctly the general framework by which the walls are, so to say, bound together, and by which the whole is covered to protect it from the inclemency of the weather. In this class of work the timber is left with its surface rough, just as it comes to the hand of the workman from the saw mill, or as it is imported direct from the "lumber" works of the forests of northern Europe, in the Old World, or from those of America in the New, from which our supplies of timber are obtained. And while referring to the term "forest," it is curious and suggestive to note that the distinction between "timbers" and "woods" in relation to size which we have observed is carried out more or less in the case of the places where timber is grown. Thus we know pretty well generally that when we talk of "woods" we refer to tracts of land under timber comparatively limited in extent, and bearing trees not very large or very old; when we use the term "forests" we mean more extensive tracts, including very large and very old trees, and very numerous.

General Character of the Work of the Joiner.

Leaving the specific work of the carpenter (see "The Carpenter"), on the other hand we find that the joiner takes the material in pieces of comparatively small size or bulk, and cuts them into the form or shape and the dimensions necessary for certain "fittings" of the house—the surfaces in all cases being made clean and smooth; this being generally done by the operation of "planing." The "fittings" of a house in wood, or "joiner's work" as it is generally termed, come under two classes—exterior and interior work. The exterior work comprises the external, front, back, or street doors—the window frames, and where stone work is imitated in wood; bay and bow window work, eaves, cornices, barge boards, etc., etc. The interior work comprises the floor proper, or the surfaces on which we tread, known as "flooring boards," the finishing of these at the parts where they join or come up to the walls, known as "skirting boards," "dados," and the like; the interior furnishings of the windows, as in sill, architrave, shutters and shutter-boxes, interior doors with their architraves, and panelled work. Chimneypieces formerly constituted an important part of the work of the joiner. But wooden constructions are now almost wholly superseded by stone, marble, enamelled slate, and for bed and less important rooms cast-iron chimneypieces. A very important part of the work of the joiner is the design and making of the wooden staircases by which communi-

cation is had from one floor to the other—and in connection with this the department of hand-railing. The class of work done in those two departments—staircasing and hand-railing—is in many cases so difficult, and involves, especially in the case of hand-railing, so many intricate problems, that they are frequently pursued as a distinct trade. The various inside fittings of a house, such as shelving, etc., all come under the domain of the joiner, who also undertakes all the iron work connected with doors and windows, etc., etc., and which—as hinges, latches, locks, etc., etc.—are known generally as "furniture," such as door furniture, window furniture.

Brief Historical Glance at the Art of the Joiner—Its Technical Suggestions.

In considering the relative antiquity of the two trades, the carpenter and the joiner—although the two are frequently combined in one individual—there is no doubt that the palm of seniority must be awarded to the trade of the carpenter. Shelter was a primary necessity (see the series of papers entitled "The Carpenter"). And this, as we have seen from those papers, would at first, and for long, be of the roughest and rudest kind. But as the arts of civilisation multiplied, the demands for mere shelter from the inclemency of the weather would be supplemented by those which a desire for some thing more than shelter—namely, that for comfort—would evoke. And as wealth increased those internal fittings, which at first would be of the simplest kind, would be made more luxurious, and both in general form and in detail would begin to minister to that taste for the beautiful which seems to come with increase of comfort and of luxury. We can easily conceive, then, that at first, as the interior fittings would be rough and heavy, and the conveniences clumsy, the carpenter who had framed the timber work of the house would take in hand the making of those fittings. And it would only be at a later period, when the fittings became of a lighter character and more ornate in design, and consequently more difficult in construction, that finer and more costly tools would be required than those in use by the carpenter, and in keeping with the tendency to promote division of labour, which naturally brings with it an acquirement of greater skill, and which was early developed in the progress of civilisation and its varied arts, the making of the interior fittings of houses would become a distinct branch, and the special trade of "the joiner" would become established.

Subjects to be Treated of in the Present Paper.

In the present series of papers we intend to explain and illustrate not so much the tools and appliances with which the joiner works—

as those can only best be understood when seen, handled, and worked with, or seen as worked by the hands of a skilful workman—as his actual constructions and their details. Our illustrations will, therefore, have reference more to the form which certain parts assume, or their design, than to the way in which they are made by tools,—more as to *what* is made or done at the bench than *how* it is made. This latter part of the joiner's duty can only be learned thoroughly by working at the bench, seeing how the work is done, and by long continued practice in the doing of it. This plan or mode of treatment does not preclude us, however, from giving sundry hints incidentally, or more systematically as occasion serves, as to how work should be done. As to which point all that is at present essential to say is that the work should be honest work—the very best which the workman can give; no shirking, or "scamping"—as the graphic phrase of the workshop puts it—being at all admissible. If the very best which the young joiner can give be not the best which is wanted, that best will come in due course in virtue of practice and a dogged determination to succeed "Rome was not built in a day," and finished workmanship is only reached by patient and honest practice. Some may reach it quicker than others, for abilities vary with different men. But although the progress be slow, still if improvement be clearly made, the young workman must not and need not be discouraged: quickness will come with practice, and good work also—the one thing required in all cases being a determination to do one's very best.

Classification of Joints.

The first department which shall engage our attention will be that of methods of joining pieces of timber together which are placed or lie when joined in certain special relations to each other. This department is technically termed "joints," and bears the same relation to the finished or completed parts as the "joints" of "The Carpenter" bear to the finished constructions—as floors, partitions, and roofs. Of the joints used in the joiner's art it is not easy to give a precise classification in definite groups or families. This does not arise so much from their mere number—although this, as will be seen, is great; but because several, so to say, overlap each other, and are dependent upon or are related more or less closely to some other. Some again so overlap with, or in principle so closely resemble, similar joints in carpentry, that it is not easy to separate the two by any distinct line of demarcation. In the present work this will not practically much concern us; inasmuch as both arts—that of the joiner and that of the carpenter—will

be found treated of in its pages. A classification of the joints used by the joiner into groups sufficiently precise to enable easy reference to be made, so as to become acquainted with their charac teristics, may, however, notwithstanding what has been said above, be made, and will be here attempted. We begin with the joints used in joining two or more pieces, each comparatively narrow, and of equal, or it may be of unequal, breadths or widths, in order to form a flat surface, such as a simple door. (See a succeeding chapter on the different forms of doors in use.) When the separate pieces joined together are placed in their permanent position, in which they are subjected to certain strains tending to separate them, after they are joined individually, or rather after two or more contiguous pieces are joined, they are collectively held together as one piece by certain methods which again may come under another classification or group of joints.

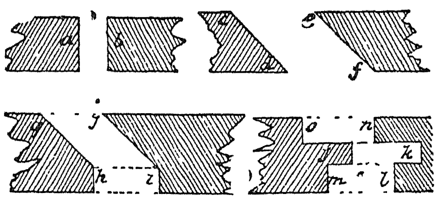


Fig 1

Joining of Boards together to form a Broad Surface.—"True" or Perfectly Flat and Square Edges in Joined Boards.

This is one of the cases alluded to above, in which two groups overlap each other, so to say, or are used in conjunction. In the group in question, the primary idea of the joint is to place two contiguous boards in relation to each other, so that their edges shall touch one another throughout the whole length, the joined piece, or "board" as it is technically termed, forming a flat surface, of which the breadth is equal to the sum of the two separate pieces. The simplest of all the joints in this group is obviously formed by preparing the edges of each separate board in such a way that the surface of each edge shall be perfectly straight—or "level," as some would call it—from end to end, and that moreover each edge shall in relation to its breadth or width—that is, the thickness of the board or plank—be at right angles to its faces or flat surfaces, and that at any part of its length wherever tested by the "square." An edge thus formed—the tool called the "plane" being used to produce it—is called a "true," or a "perfectly true," edge; and when two

such edges are brought in contact, as at *a* and *b* in fig. 1, the joint is said to be a "true joint." In some cases, as where a joint pretty fairly air- or water-tight is required, or for other reasons, the edges, in place of being at right angles to each other as at *a* and *b*, are made to slope, or are "bevelled" or "splayed" off, as at *c d* and *e f*. Those when joined or placed together give a less direct course, so to say, from one surface to the other, or to the line of joint. So also in the forms of joint at *g h*, *i j*, in the same figure. In this case, as in the joint at *a b*, the edges *g h* and *e f* must be perfectly "true"; the angle being once decided upon, and the "bevel square" set to that angle, the face must be true to that at any and at all points in the whole length of the joint. If this be not secured, as also in the case at *a b*, the joint will not be "true," and the two pieces will not be square or flat, but will "ride" or jog or jolt when moved. Absolute "truth" is requisite in all joints.

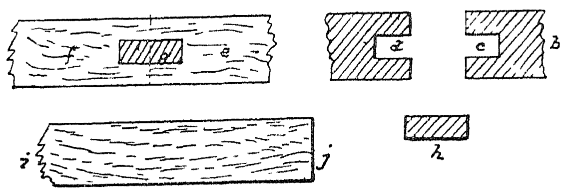


Fig 2

Joining of Narrow Boards together Edge to Edge to form Broad Surfaces.

It is obvious that, however accurately the edges at *a b*, *c d*, in fig. 1, may be made, the two pieces when put together will be separated with extreme ease. In rough work nails may be driven in diagonally at each end, and at various parts of the length of joint. But in superior work, where joints technically termed "fair" are required, methods other than this rough, if ready, mode of keeping the boards together are adopted. In fig. 2, the joint used when boards are "tongued and grooved" is illustrated. After the edges, as *a* and *b* in fig. 1, are planed or made "true," a recessed part, technically called the "groove," is "ploughed" out by a plane used for this purpose, along the centre of the edge, shown at *i j*, fig. 2, the full length of the board; this is shown in section at *c* and *d* on the edges of the two boards *a* and *b*. The two boards thus grooved on their edges are brought up edge to edge, and a long, narrow and thin strip, technically called the "tongue," but considered as a separate piece frequently termed a "feather," is driven

in tight, as shown at *g*. Or the one half of this—shown in section at *h*—may be driven in the groove of one piece, *f*, and when in place the groove of the other piece, *e*, may be passed over the projecting part of feather or "tongue," and then "driven home," as the technical phrase has it. The tongue or feather *g* or *h*, while fitting the space formed by the two grooves, when the pieces *a* and *b* are brought together, as at *e f*, must not fit too tightly, as when "driven home" it is apt to split the sides of the groove. Another method of joining boards together edge to edge is shown in fig. 1,

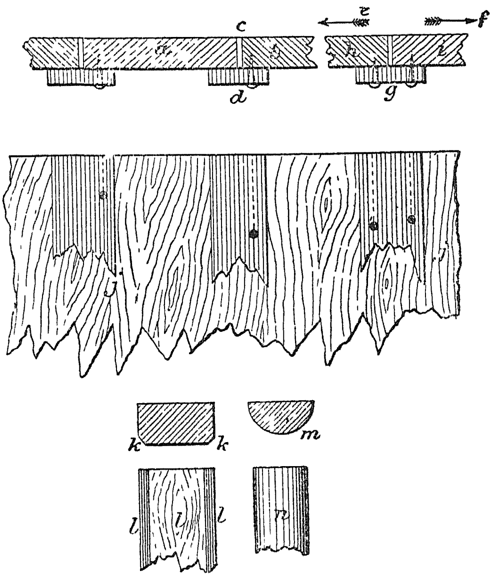


Fig 3.

at *j k l m n o*, in which the projecting part at *j*, or tongue, enters the groove *k*, the edges *l* and *m*, *n* and *o*, butting or lying against each other. This forms a secure and an air- and water-tight joint; and many modifications of its principle will be met with in the illustrations yet to be given.

Joining of Boards with Ribs—Precautions to be taken in Nailing on the Ribs to the Boards.

A very simple method of joining boards or planks together, edge to edge, is shown in fig. 3; the two boards *a* and *b* are brought up

edge to edge at *c*, and the joint covered with a "slat," "batten," "rib," "firring-piece," or "bar," *d*, or "roll," *m*, broad enough to pass some distance beyond the joint on each side of it. This method is generally adopted in the construction of superior sheds and timber houses. In work of this kind, as the boards *a* and *b* shrink laterally, tending to separate from each other in the direction of the arrows *e* and *f*, widening the joint at *c*, great care must be taken to nail one rib or feather, *d*, to *one only* of the boards, either *a* or *b*. If nailed to both boards, a rupture either of the rib *d*, or the edge of one of the boards or the edges of both pieces, will be almost sure to take place, giving ugly splits, and destroying the integrity of the connection as a good air- and water-tight joint. This splitting of the wood is caused by the great power of shrinkage of the boards *a* and *b*, and which being, as it were, encountered or resisted by the rib *d*, preventing them separating, the shrinkage force is greater than the tenacity of the small part of the edges of which the nails take a hold, so that part gives way. But when one rib *d* is nailed to one of the boards, as *b* only, as we have shown is the rul in sound work; when the shrinkage takes place, the board *b* is free to move away from the board *a* with its nailed rib *d*, so that no strain is thrown upon the board *a* and rib *d*. When a shrinkage ceases, and swelling of the boards takes place, as in damp weather, the boards meet again at the edges *c*. To allow of the boards giving and taking a little in case of damp weather, the joint *c* should have a little "play" given to it—that is, the boards *a* and *b* should not be allowed to be pressed up very closely together when the rib *d* is nailed to one of them. When the ribs, as *g*, are fastened by two nails, as shown in fig. 3, the action of the expansion of the two boards, in tending to split the wood, is represented by the arrows *e* and *f*. In fitting up boards in this way, the "joiner" will have to exercise his judgment, dependent upon the condition of the boards and the state of the weather at the time of fitting them up. Allowance will have to be made when the boards are damp or ill-seasoned, or *vice versâ*. The elevation is shown between, at *j j*; the ribs, as *d*, are in superior work splayed or chamfered, as at *k k* or *l*, or made half round, as at *m n*.

Joining of Boards Edge to Edge by Sunk Feathers or Ribs—Rebated Edges.

Another method of joining and securing boards together is illustrated in fig. 4. In this each board is either worked or tooled by hand, planed or cut by a machine, so as to leave the edges formed as at *e* and *f*. This form of edge is technically called a "rebate." When two boards are placed edge to edge together, spaces are formed between them, running along the whole length of the boards. Into

those spaces, tongues, fillets, feathers, or slats, of section as at *h* in fig. 2, of dimensions a trifle less than the size of space, are passed into it, and secured by nails which may be driven in at the back—the nails, as in the case of the method at *a b*, being driven in at one board only. The "fillets" are shown in place at *g* and *h* in cross-section, and at *i* and *j* in front elevation.

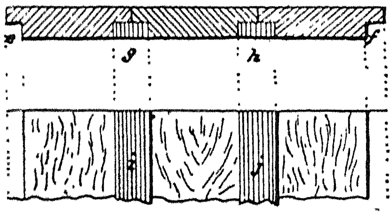


Fig. 4.

Joining of Boards—Quirk Moulds, tongued and grooved, and with Quirk Bead.

A modification of the method shown at *j k l m n o* in fig. 1 (*ante*) is illustrated in fig. 5, as at *a b* in elevation, and as at *a' b'*, *a'' b''* in section; the boards being alternately tongued and grooved as at *a'* and *d'*. The edge on the face of the boards or planks *a* and *b* is finished with a moulding known as the "quirk" moulding, as shown

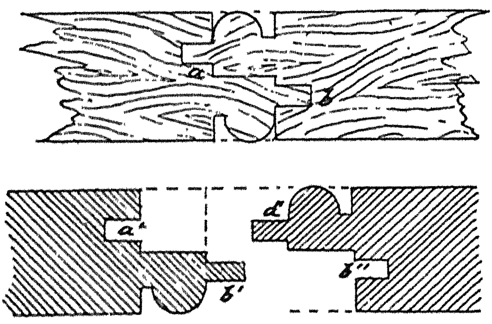


Fig. 5.

at *b'*; the other face may have only plain joints, or the edges of both boards may be provided with quirked mouldings, as in the drawing.

In the preceding figure we show the form of joint with "quirked" moulding or bead, in which the boards joined are free to give and take without making open joints. These ornamental joints are used in superior work only. In some cases the flat side is

relieved by making at the joint an angular groove; this is done by taking off the corner or angle of each adjoining edge. This taking off the sharp corner is called "taking off the arris," the angle being the arris. The same operation is in other cases called "chamfering." (For what are called "chamfers" and "stop-chamfers" see a succeed-

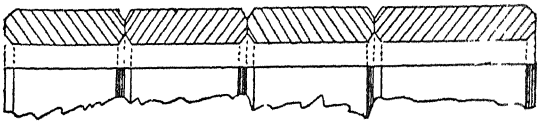


Fig. 6.

ing chapter, and b' and c' in fig. 25.) In brick and stone work the same operation is called "splaying" or "bevelling"—a corner being said to be "splayed" or "bevelled." The boards sometimes have the "arris" taken off at the corners of both sides or faces; when a

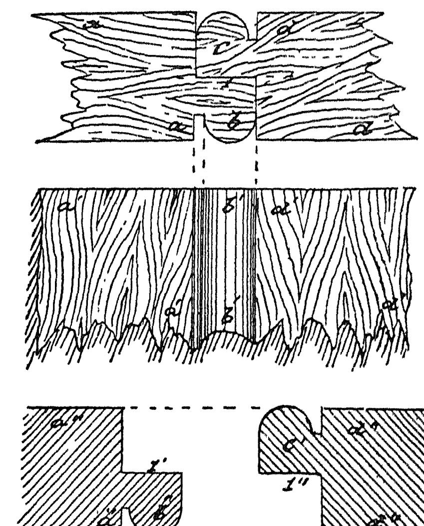


Fig. 7.

number thus treated are put together edge to edge they assume the form in fig. 6, the upper part of the diagram being in cross section, the lower in elevation. A simpler form of the quirk bead joint for boards joined edge to edge is shown in fig. 7, in which the

various parts corresponding in the different views are indicated by letters, plain and accented.

Securing Boards joined Edge to Edge by Ledges.

Boards having their joining edges treated in the methods now described in figs. 1 to 7 inclusive, are secured together as in the case

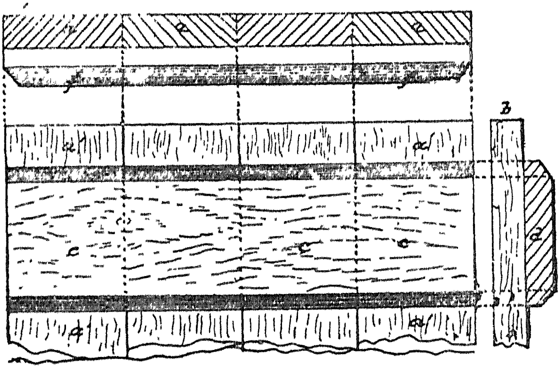


Fig. 8.

of a door, braced or ledged, not panelled (see a succeeding chapter for descriptions and illustrations of the various forms of doors), in various ways. In fig. 8 we illustrate a method very generally adopted in the simpler form of doors, known as a "ledged door." In this case the boards are laid edge to edge with plain joint, as

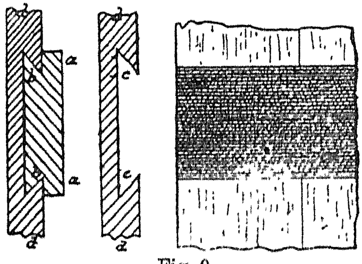


Fig. 9.

shown in the cross section at *a a a*, fig. 8, and in elevation at *a′ a′ a′ a′*; and in number sufficient to make the surface of the breadth required. A flat, broad "ledge," "batten," or cross-piece, *c c c*, with the "arris" taken off, or chamfered, at each edge on the upper side, is nailed across the surface of the boards *a a′ a′*, and secured by nails or

screw-nails; the latter in good work. This batten is usually placed at some short distance from the upper ends of the boards *a′ a′ a′*, as shown, and another batten is placed at the bottom end of the boards. The whole are shown together in side elevation at *b b*, *d*; *d* being the ledge or batten, and *b b* the edge view of the boards. In the cross section at *a a*, *b b* shows the upper edge view of the ledge *c c c*.

Securing Boards by a Dovetailed Ledge or Cross Batten.

In place of the ledge or batten being nailed on or screwed to the surface of the boards, it may be secured as in fig. 9. In this method a "dovetail" groove or mortise (see Dovetails further on), *c c*, is cut in the face of boards *d d*, as shown in face or front elevation at *a′ a′*. The "ledge," "batten," or cross-piece *a a* is formed with a

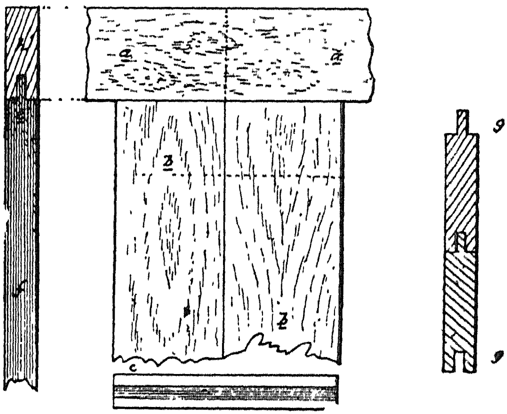


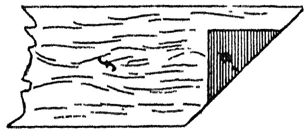
Fig. 10

dovetail tenon, *b b*; thus filling up the dovetail mortise *c c* in piece *d d*.

Securing Joined Boards together by means of Cross-pieces or Rails with Surfaces Flush throughout.

In joining boards edge to edge in order to form a larger, that is, broader or wider surface, by the methods shown in figs. 8 and 9, the "ledges" or "battens" *c c*, fig. 8, and *a a*, fig. 9, project from the surface of the boards. In superior work the surface of the united boards is generally desired to be "flush" or even. A method of joining and securing boards placed edge to edge together with the surface of the cross-piece or "flush" with the surface of the boards is illustrated in fig. 10. In this method the cross-piece, as *a a*, runs

along the termination of the boards *b b*, which are all cut off "square," but are not left plain, being provided with a "tongue," "feather," or projecting rib, as shown at *c* in edge view *f*. This takes into a groove ploughed out on the edge *c c* of the cross-piece *a a*. The thickness of the cross-piece *a a* is the same as that of the boards *b b*, so that there is no projecting part at the junction, but the surfaces of both coincide or run into one another. The tongue *e* and ploughed groove *c c* in lower diagram are of course made in the centres of the batten *a a* and boards *b b*, *c c*. In superior work the boards *b b* themselves may be joined together by the method illustrated in fig. 2, and as at *g g* in fig. 10.



Joined Boards secured together with Cross Rails and Vertical Styles.

Another method of securing the boards together when placed edge to edge is illustrated in fig. 11. In this the boards, as *a a*, are enclosed within a species of framing with two side "styles," part of one of which is shown at *b b*, and a cross-piece or "rail" *c c* connecting these. The method of joining these two members will be described in a future part of this work when we come to illustrate methods of joining pieces in different relations to each other, as pieces at right angles, shown in this diagram. The boards *a a* may simply be jammed tightly up against each other by the side styles *b b*; or better and more secure work will be obtained by ploughing the inside edges of the side styles, as *b b*, and the inner and lower edge

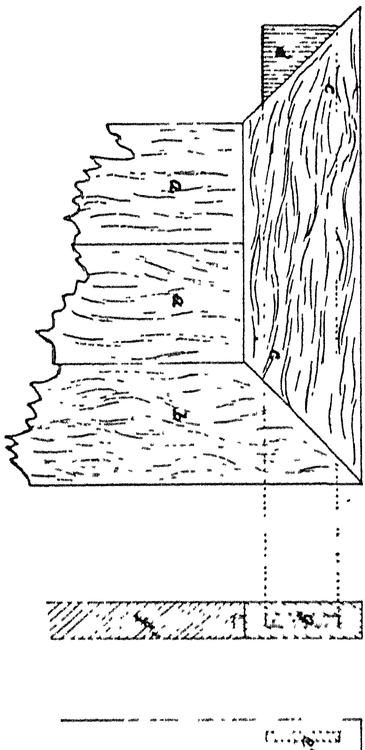


Fig. 11.

of cross-piece *c c*; and finishing the outside edge of *a* and the upper ends of all the boards with a tongue; or all the members may be secured together, as at *e* and *g* in fig. 10. The boards, as *a a*, may either be brought up edge to edge with a plain joint, as in fig. 11, or the junction at edges may be finished to show as at *g h* in fig. 4, or as in figs. 5 and 7, *f* is the other style or side-piece corresponding to *b*, with upper part in section showing mortise at seat for tenon *d*.

As elsewhere stated, the joints of "joinery" and those of "carpentry" in several instances are so similar, at least in principle, if not in detail, and, so to say, overlap each other, that it is difficult to draw the line which separates them; the only practical difference between them being this, that joinery deals with small, carpentry with large masses or pieces of timber. Several of the joints illustrated in this paper are examples of this peculiarity.

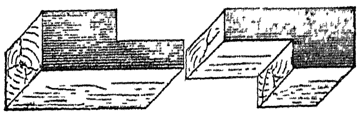


Fig. 12.

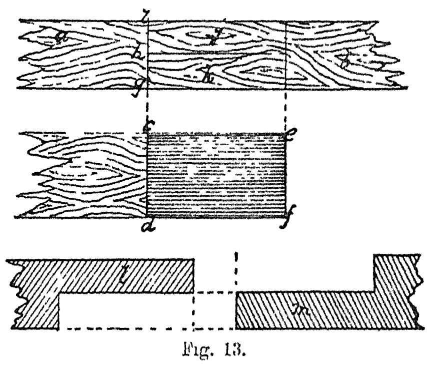


Fig. 13.

Joints used in Lengthening Pieces—The Half-lap Joint.

We have just said that the joints of "Carpentry and of Joinery" were similar in principle: an example of this is found in the illustration now to be given, which forms one of several methods used to lengthen one piece by having another piece added to it. Fig. 12 illustrates a well-known form of joint, known as the "half-lap"; fig. 13 shows this in detail, *l* and *m* being longitudinal sections of the parts *a* and *b* in side elevation; *c d e f* shows in plan the part

cut out to half the depth across the line *g h i*, *j k* being the line of junction of the two surfaces. The parts may be secured together by a pin, as at *c* in fig. 14, but this joint is weak to resist any side or lateral pressures, as indicated by the arrow *d*, which will tend to displace the part *a* acting upon the pin *c* as a centre. The lower

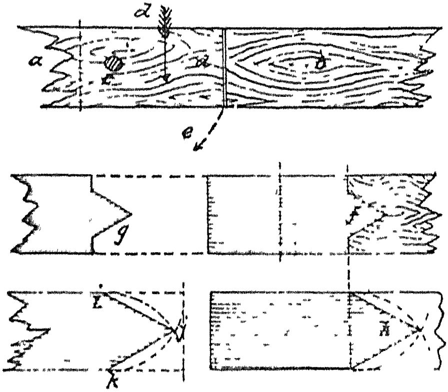


Fig. 14.

part of the diagram shows how this lateral strain may be met; the end of pieces, as *a*, being provided with a projecting angular part, *g*, which goes into a correspondingly-shaped recess or part cut out, as at *f*. Or the end may be formed as at *i j k*; the recessed part as at *k*.

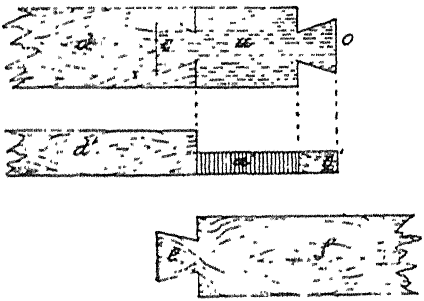


Fig. 15.

Other Forms of Lengthening Joints—The Dovetail Joint The Tongue and Groove, or Ploughed Joint—The Ploughed or Grooved with Feather Joint.

Fig. 15 illustrates another joint of the same class as last described, in which the pieces joined with a half-lap joint, as in fig. 12, have

dovetail tongues, as at *o* and *e*, which go into corresponding recessed

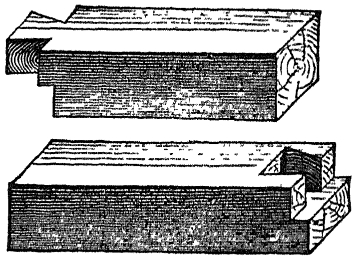


Fig. 16.

parts, as *c* in plan. Fig. 16 is a modification of this. Other forms

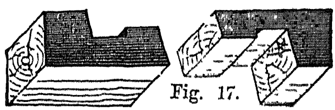


Fig. 17.

of joints in this class are shown in figs. 17, 18, 19, and 20. Fig. 18

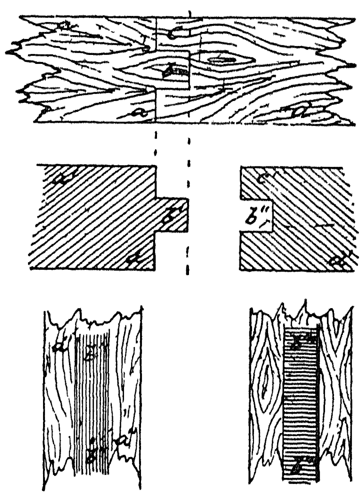


Fig. 18.

is the "tongue and groove," or "tongued and ploughed" joint, the

same as used in joining boards edge to edge. Fig. 19 is a double

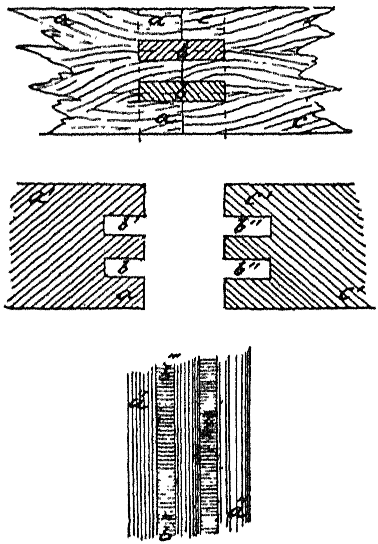


Fig. 19.

tongue and groove joint, and fig. 20 illustrates an adaptation of the

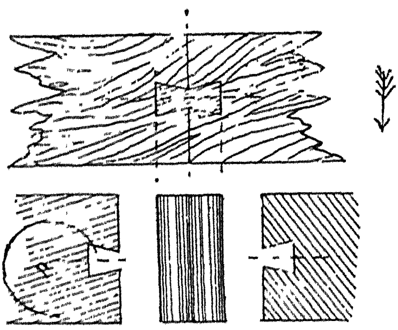


Fig. 20.

"dowel" used in masonry. The "feather" used, rectangular in section, as *g* in fig. 2, is here, in fig. 20, double dovetail.

Joints used in Lengthening Pieces—Modification of the Half-lap Joint.

Fig. 21 illustrates a joint in this class which may be looked upon

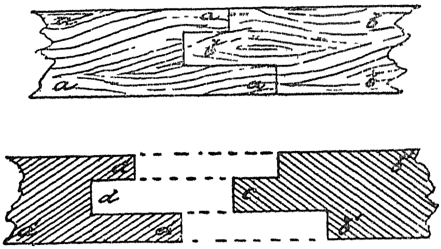


Fig. 21.

as a modification of the "half-lap" joint in fig. 12, *ante*, but in which the projecting part *c* of piece *b b* goes into the recessed part *d* in

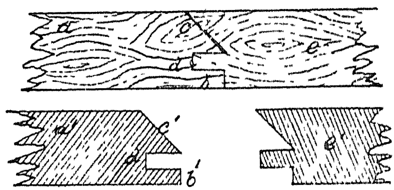


Fig 22.

the piece *a′ a′*. *a a*, *b b*, show the parts put together in side elevation. Fig. 22 is a modification of this with a sloping face or table *c*, and

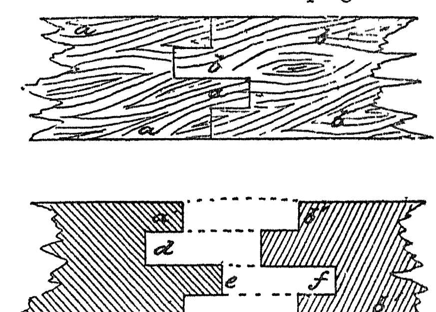


Fig 23.

a projecting horizontal part *d*. Figs. 23 and 24 are more complicated forms already described in connection with figs. 5 and 7, of this class

of joint. Fig. 25 gives in detail the joint which may come under the present class; the corresponding accented letters show corresponding parts of joint. Those joints, especially figs. 23 and 24, come also,

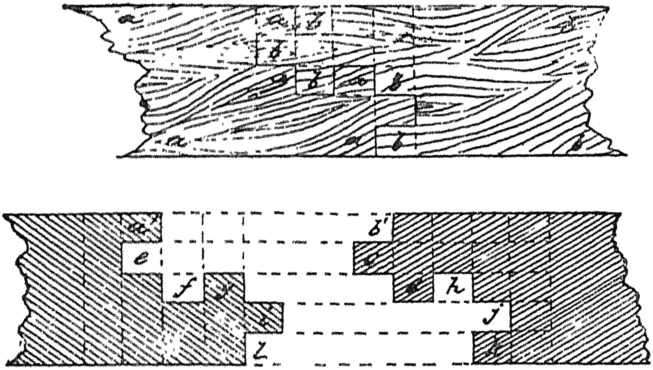


Fig. 24.

and perhaps more accurately, within the range of carpenter's work for large beams.

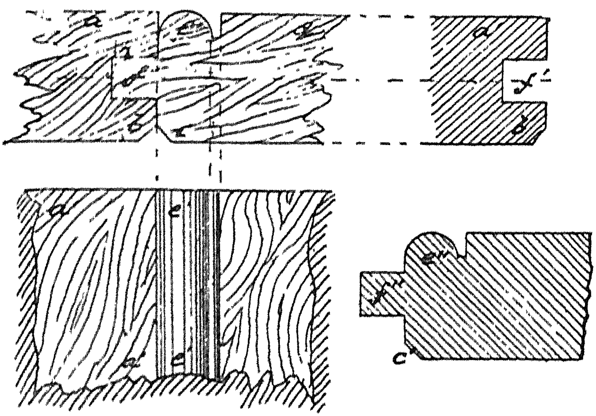


Fig. 25.

Tongued, Ploughed, or Grooved Quirk Bead Joint.

Fig. 25 is a joint of the same class illustrated in figs. 5 and 7. The accented letters indicate the separate details to the right. The upper diagram to the left shows the two pieces in edge or side

elevation; the lower diagram the front elevation of the pieces. In this only one side or face of the pieces is finished with a quirk bead, as at *e*. The other side is flat, save where the edges of the two pieces are splayed or bevelled—*i.e.* have had the arrises taken off at the joint, as at *b* and *c*. This is referred to in connection with figs. 5 and 6.

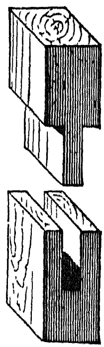


Fig. 26.

Joints used in Joining Pieces Vertically to each other.

We now come to those in which pieces are joined vertically to one another, and those in which the pieces are at right angles to each other. Fig. 26 illustrates two pieces joined vertically by what may

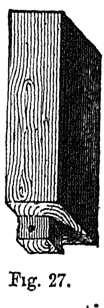


Fig. 27.

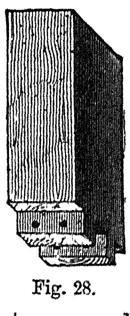


Fig. 28.

be called the open mortise, but which is the tongue and groove joint already described. The groove is cut out in the lowest piece, the tenon being cut on the end of the upper piece. Figs. 27 and 28 show the same joint, but for closed mortises—one single, as in fig. 27,

and one double, as in fig. 28. In both cases the tenons are dove-tailed, not plain as in fig 26. Fig. 29 illustrates a method of joining two pieces at right angles: in the upper diagram the horizontal piece is joined to the side of a vertical piece by a dovetail tenon; in

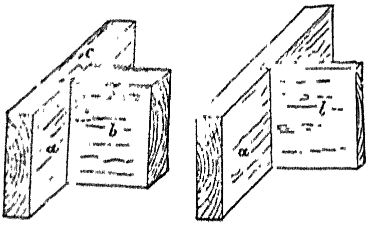


Fig. 29.

the lower diagram a vertical piece is joined to a horizontal-lying piece by being simply let into a groove cut in the lying piece of a width equal to the thickness of the vertical piece. In fig. 30 we give a

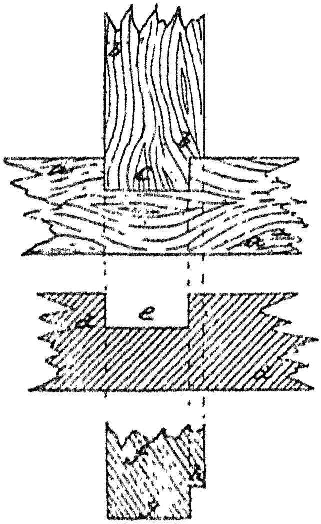


Fig. 30.

detailed drawing of another method of making a joint, where one piece, as *b b*, is vertical to another piece *a a*. In this the groove is not cut in the piece *a a* of full thickness of the piece *b b*; but only

of a certain part of this; the end of *b b* being cut off so as to form a shoulder as at *h*, allowing the part *c* to enter the groove *e* made in the piece *d d*. This shoulder in *b b* allows of part of *b b* butting solidly on *a a*, thus relieving the groove *e* from any lateral pressure exercised by the piece *b b*.

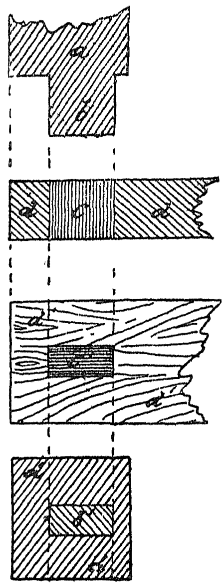


Fig. 31.

Vertical Joint with Mortise and Tenon.

In the last form of joint illustrated the groove *e* is cut to a certain depth only, and across the full breadth of the piece *a a*; the width of the piece *b b* being supposed to be equal to this breadth; but in the joint in fig. 31 the width of the horizontal piece, as *d′ d′*, is greater than the thickness of the piece *b b*, which is to be jointed vertically to it, and which is to occupy the centre of the width *d′ d′*. The joint is effected by mortise *c′* and tenon *b* cut in the end of *a*. The mortise *b′* and *c′* is cut through the full thickness of piece *d′ d′*, so that the end of *b* may be wedged up from lower side of piece *d′ d′*. The tenon *b* is not of the full width of *a*, but is cut so as to give a shoulder at both sides of the tenon *b*, as shown.

Joints for joining Horizontal with Vertical Pieces.

Fig. 32 shows a method for joining a horizontal piece *a* to a vertical piece *b*, both of which are of the same thickness, by a dovetail tenon shown in side elevation at *g*, and a corresponding mortise *h*.

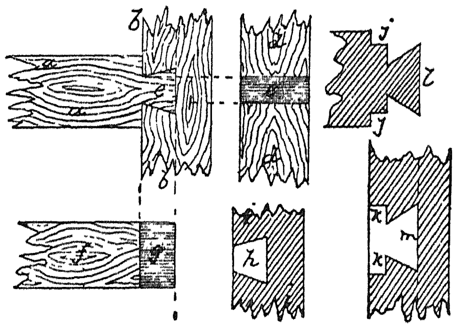


Fig. 32.

This is cut the full width across the face of vertical piece *d d*, as shown at *e*. In place of making the tenon as at *h*, in *i i*, it may be cut with shoulders, as at *j j*, on each side of the tenon *l*, corresponding

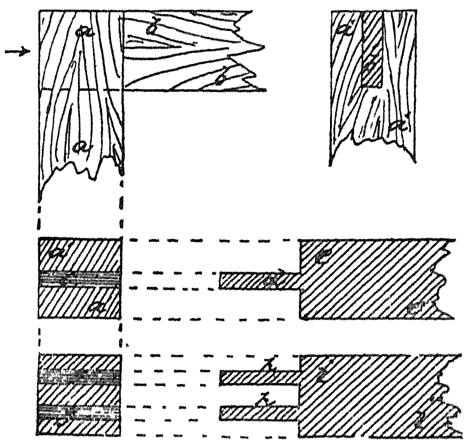


Fig. 33.

undulations or hollow parts being cut out as at *k k*, *m*. Pieces at right angles to each other, as in preceding figure, are met with in framework very frequently, the pieces being generally of the same

thickness, and often, though not always, of the same breadth. Thus, in fig. 31, a' and b' are parts of pieces joining as at the corner of a framing. In cheap work, the joint may be made on the "half-lap" principle, illustrated in fig. 12 (*ante*); a part equal to the breadth of the piece in length being cut out at the end of each, as shown by the dotted line on piece *a a*, fig. 33; the thickness of the piece cut out of each end being, of course, equal to half the thickness of the piece; and as the thickness of the two pieces is the same, the result is that when the two pieces are put together the surfaces will be flush on both faces. The two pieces will have to be secured together by nails or otherwise. But in a higher class of work the "tenon and mortise joint," as in fig. 26, may be used, as shown in fig. 33, in which a' a', to the right at top of diagram, shows the edge view or thickness of piece *a a*, having an open mortise b' cut in the centre of its width and at the extreme end, the depth of which is equal to

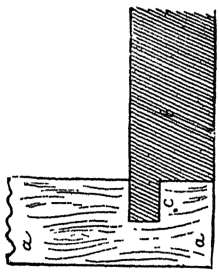


Fig. 33A.

the breadth of piece *b b*; this is shown at *e e* with the tenon *d* cut at the extremity, which is driven into mortise b' in a' a', end view *d e e* being at *c* in a' a'. Or a double mortise and tenon joint may be used, the double tenon being as at *f* and *g* in end view, and *h h* in face view *i i*. For the joint thus made will be secure against any pressure acting in the direction of the vertical arrow 2, or horizontal one as shown in upper figure to the left; but pressures acting in directions opposite to those directions will tend to draw out the tenon from the mortise laterally or force it up vertically. To keep the whole in place, a wooden pin may be used, inserted into a circular hole cut through the piece *a a* and the tenon *d*. In fig. 33 A we give another form of this class of joint, in which the horizontal piece *b* is secured to the vertical piece *a* by the grooved and tongued part at *c*.

A Modification of "Dovetail" Joining, as at the Corners of Two Pieces meeting at Right Angles.

In fig. 34 another form of joining pieces, as at the corner of a frame, is a modification of the principle of dovetailing, in which the mortise and tenon, in place of being plain surfaced, as in the last

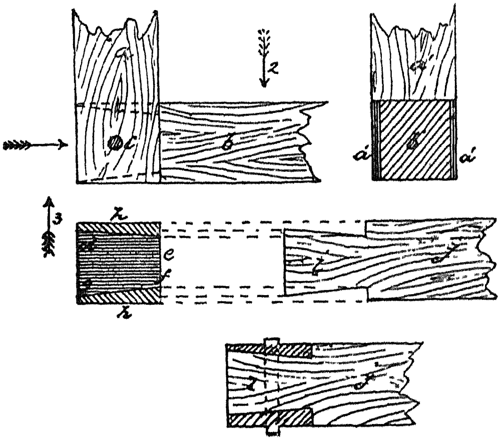


Fig 34.

figure, are dovetailed. The mortise cut in the piece *a a* is cut across the end, and is open to this, as shown in end view at *d e f g* in *h h*; the depth being equal to the breadth of piece *b*. The end of piece *b* is cut out with a tenon as at *i* and *j*, and when the two pieces are placed together by inserting the tenon *i* in the mortise *d e f g*,

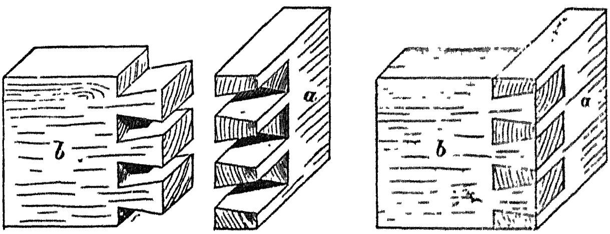


Fig. 35.

on looking at the edge view at *a′*, of piece *a* in the direction of the arrow 1 to the left of the upper figure; the end of tenon *i* is seen at *b′* in cross hatching. Looked at in the direction of arrow 3, the whole presents the appearance as at *h′ h′*, *i′* and *j*, those being the same parts as those correspondingly lettered without the accent.

Pressures tending to separate the pieces are prevented by the form of the joint here employed, excepting in the direction of the arrow 2; and to meet this pressure or separating strain, a pin as at *c*, or in edge view at *i*, is passed through the two pieces from side to side, and finished off flush with both surfaces, not allowed to project, as

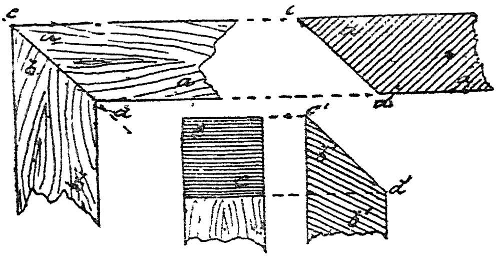


Fig. 36.

shown in the diagram at *i*. When the dovetail principle of joint is applied to work, as to small boxes, or in a very complete way in larger work, the double dovetail is employed, as illustrated in fig. 35. In this form of joint it will be perceived that strains tending to

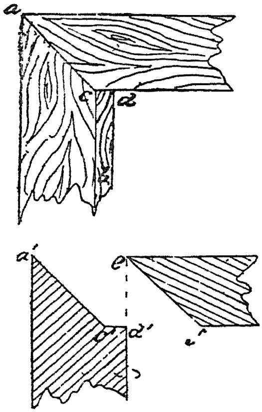


Fig. 37.

separate the two parts *a* and *b* are met in both directions by the angular form being given on both sides.

The "Mitre" Joint.

Pieces as in framework are joined at right angles by what is

called the "mitre" joint. In the illustrations already given, the end of each piece is cut off at right angles to the length. But in the "mitre" joint each end is cut off at an angle of 45° to the length, as in $c' \ d'$ of the piece $a' \ a'$, or $b' \ b'$, fig. 36. When pieces thus cut

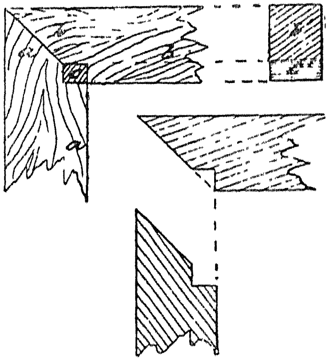


Fig 38.

are joined face to face, as $c' \ d'$ of $a' \ a'$ to $c' \ d'$ of $b' \ b'$, they are exactly at right angles to each other, or square, as at $a \ a$ to $b \ b$, and the joint $c \ d$ is termed a "mitre" joint. A side view of piece $b' \ b'$ is at

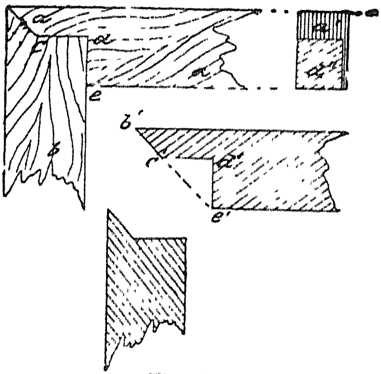


Fig. 39.

$e \ e$. The pieces when placed in position must be glued or otherwise secured. A mitre joint sometimes used is illustrated in fig. 37, in which a shoulder, as at c, is cut in the piece $a \ b$, giving the end of the form as at $a' \ c' \ d'$.

The end of the piece *a b*, fig. 37, to be joined, is cut with a mitre—that is, the face, as *e f*, is at an angle of 45° with the line of the length of the piece. A modification of this, but more complete, is shown in fig. 38, in which a double shoulder is given—a shoulder being cut, as at *c*, in piece *a a*, shown separately, a

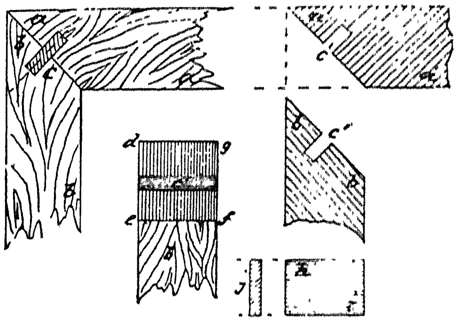


Fig. 40.

corresponding part being cut out in piece *b b*, as at *d*; *b′ c′* is end view of *b b*. Another modification is shown in fig. 39, which is a combination of the square and the mitre joint, the part from *b* to *c* only being "mitred," a square-faced shoulder or return joint being formed at *c d e*. The lower drawing in the diagram gives

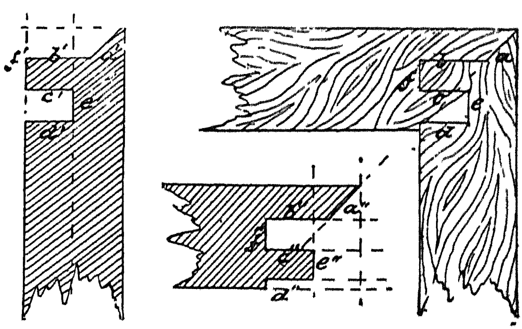


Fig. 41.

the appearance of the end of part *b b* when viewed singly, *b′ c′ d′ e′* the end of part *a a*, *a′* and *d″* is edge view of end of part *a a*, or *b′ c′ d′ e′*.

Further Illustration of Joints on the Mitre Principle.—Pieces at Right Angles.

In figs. 40, 41, and 42 we illustrate joints at corners of pieces

joining at right angles on the "mitre" principle, and which are by the form of joint employed secured from being separated by lateral strains. In fig. 40 the faces of each "mitre," as of piece a' a' and piece *b b*, has a part or "slot" or "chase" cut out, as shown at c' c'. When the pieces are placed together, as at *a a*, *b b*, these form an

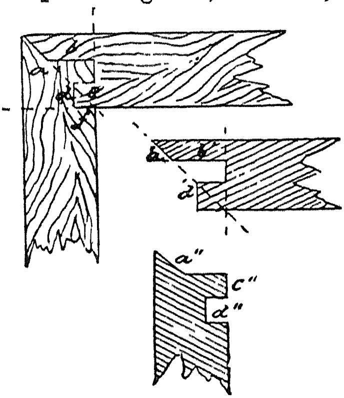


Fig. 42.

opening, as *c*; into which a "key" piece, or "dowel," exactly equal in length to the thickness of *a a*, *b b*, is driven in tight up, thus holding the two together. An inside view looking edgeways of the piece *b b* is shown at *d e f g*, being the face of the "mitre," c' being the part cut out. In fig. 41 the vertical piece *a* is joined to the

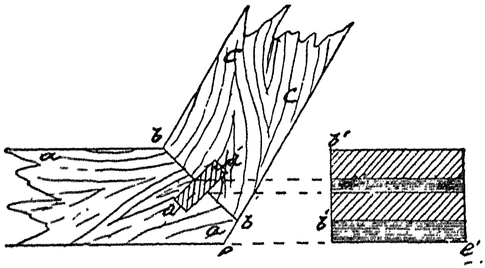


Fig. 43.

horizontal piece by a joint, of which *b f c* projects, and the part cut out at c' e' d', as shown in the diagram to the left; the horizontal piece having corresponding indentations, as b'' c'', and projection e'' d''. Fig. 42 is a more simple form of the same kind of joint, corresponding letters accented showing corresponding parts.

Other Forms of Joints for Pieces cut at Right Angles to each other.—Oblique Joints.

In figs. 43 and 44 we show forms of joints where the pieces are not at right angles to each other, but form an angular part or

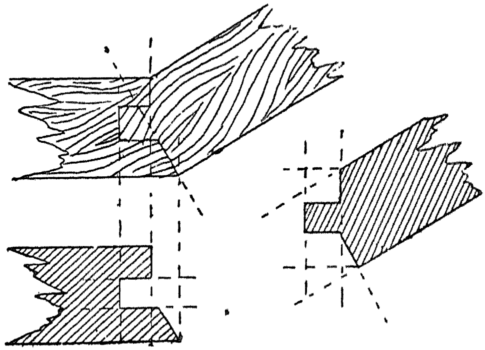


Fig. 44.

corner, as at *e*. The ends *b b* (fig. 43) of the two [illegible]s *a a* and *c c* are cut or squared off at the desired angle, transverse grooves being cut in the faces and centres of the joints, into which a dowel or feather *d d* is driven, being squared off at the ends in order to be

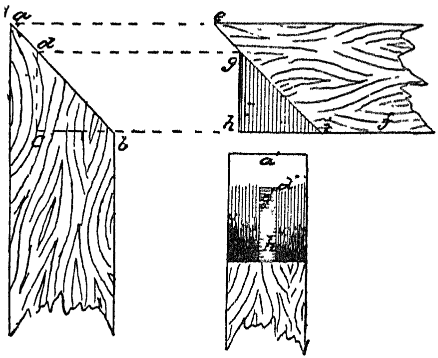


Fig. 45.

flush with both faces or surfaces of the pieces *a a* and *c*; the diagram to the right shows elevation of face of one of the pieces, as *a a*. Fig. 44 is another joint of the kind on the same principle as in figs. 43, 41 and 42.

Forms of Mitre Joints Tongued and Grooved.

In figs. 45 and 46 we illustrate a form of "mitre" joint with mortise and tenon, or tongue and groove, frequently used in joining pieces at right angles to each other. The ends of the two pieces are first "mitred" or cut off at an angle of 45° to their length, as at

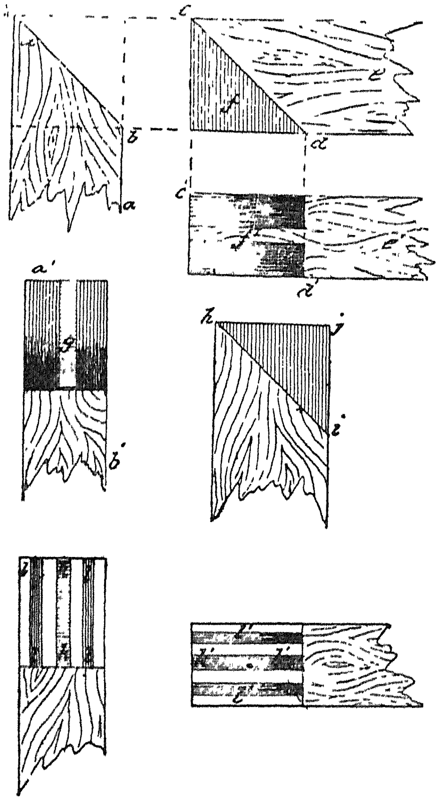


Fig. 46.

a b, *e i*. But the one piece, as *e f*, is not cut flush or across the full face, but a part, as *g h i*, is left in the centre of the thickness of face, forming a tenon or tongue. A mortise or groove, as *g h*, fig. 45, is cut in the mitred face *a b* of other piece, to receive the tenon *g h i*, and in position, as at *b c d*, corresponding. *a' d g h* is end view of

part *j h i f*. In fig. 46 the face *a b* of the end piece *a a* is "mitred"; and the face *c d* of the piece *e* mitred also, but the tenon or tongue *f* in this case extends the full length of the face of *e*, not cut short, as at *g h* in fig. 45; *a′ b′* is the elevation of the face *a b*, with mortise *g* cutting in *c′ d′* is plan of lower edge of piece *e*, *g′* being the tenon or tongue. The positions might be reversed, the tenon being cut on piece *a a*, as at *h j i*. The lower diagram to the left shows the face of *a a* as provided with three mortises; tenons are cut on the end of the other piece.

In fig. 47 we give a modification of the form of joint illustrated in fig. 46, where one piece, as a horizontal one, *h h*, joins another, as a vertical, *a a*, and that not in the centre of its edge or thickness, but at one side, so that the surfaces of the two pieces are flush, while there is a projecting part behind, as shown in side view of *a a*, at *l l*, *m m*, *n n*. The horizontal part may be simply let in by a mitre joint, and secured by a pin in the centre of the cut-out part *b c d* at *e e*. The work will be more secure if a tenon or tongue, as at *g g*, be cut in the end of the piece *h h*—this taking into a mortise or groove, as *m m*, cut in the mitre joint *l n*. The edge view of *g g h h*, looked at in the direction of arrow 3, is shown at *g′ g′ h′ h′*; *l l m m n n* being a side view of *a a*, looked at in the direction of the arrow 1. If the part cut out at *b c d* on a piece *a a*—edge view immediately below—had a tongue or tenon in its centre, as *e′e′*, the horizontal part joining it in elevation to the immediate right of *a a* at top, would have a mortise or groove cut out in it, as shown at *f f*, which is the plan of top or upper edge of horizontal piece, as looked down upon in the direction of the arrow 2. The diagram marked *k k i i j j* is a cross section of the piece *a a* on the line *b c*, when the joint is made with a tenon or tongue, as at *g g* on the horizontal piece. In those three last illustrated forms of joints the tenon or tongue, in place of being formed out of the solid, may in some cases be more easily formed by cutting or "squaring" off the mitre or angular face right across, and then cutting in its proper position a groove a little less in width than the thickness of the tenon or tongue, then driving this cut to its proper dimensions into the groove, leaving as much projecting from the mitre face as gives the required length of the tenon.

Joints finished off with Beads.—Quirked Beads.

The corners of pieces joined in the manner illustrated as in figs. 41 and 43 (*ante*), are sometimes finished off as "beads," of the class known as "quirked beads." Fig. 48 illustrates a method of joining two pieces at right angles, with a double quirked bead *b* at the end

of one of the pieces, as *d d*. The bead proper is the rounded part at *b* forming part of a circle in section; the "quirk" is the recess or part *c*, one side of which is formed by the square end of the piece *d d*. The bead *b* is formed at its upper side with a projection 2,

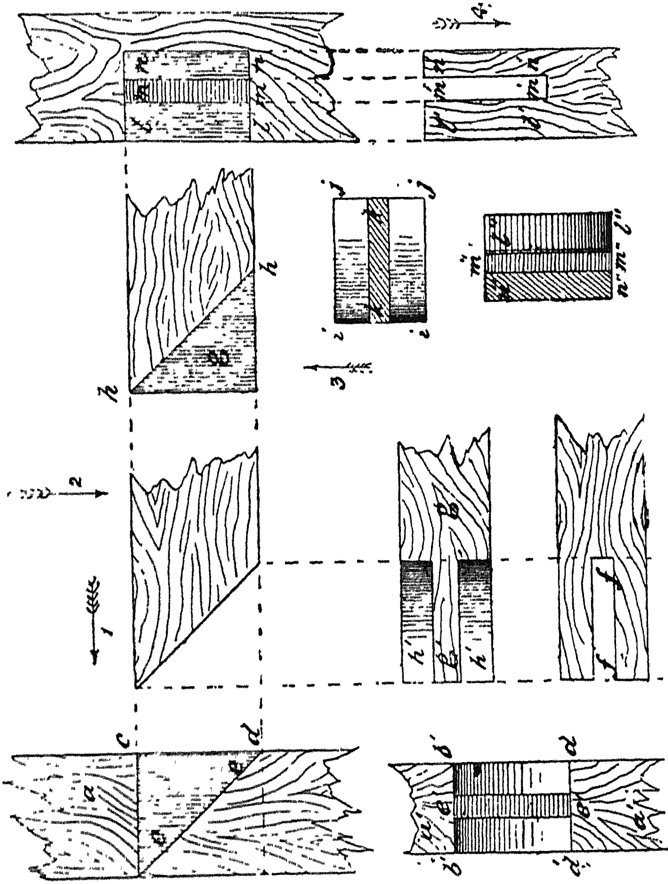


Fig. 47.

shown at 2″ in the lower diagram to the right; this projection is carried down so as to form an indentation, as at 1″, into which the part 1′—corresponding to 1 in lower diagram to the left—passes or is inserted. When the two pieces are joined together, as in the upper

diagram, the upper "quirk" corresponding to *c* is formed by the square end of the piece *a a*. In fig. 49 both pieces have beads at their ends, as at *b* and *d*; but those are single quirks, as at *e* and *f*. The junction is effected by a shouldered tenon *a* passing into a corresponding mortise in *c c*, as at *a'* and *a''*.

Joints for Angles other than Right Angles.—Beaded.

In fig. 50 we illustrate pieces joined at angles other than at right

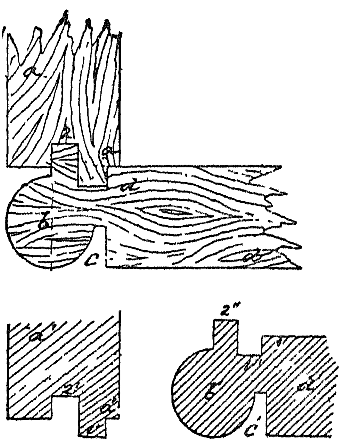


Fig. 48.

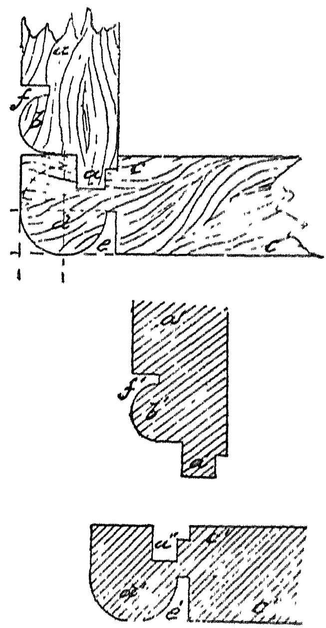


Fig. 49.

angles, provided at the meeting point or corner with a "bead" finishing; in this case a double quirked bead, the two quirks being at 4 and 5, the bead proper being at *b*. The lower diagrams show the method of cutting the ends of the two pieces, corresponding letters accented showing corresponding parts in upper diagram. In fig. 51 we illustrate another joint of this kind, in which the circular bead *b* has curved quirks 4 and 5, the ends of the two pieces being curved in place of being left square. The upper and lower diagrams

show the pieces *a a* and *c c* separately, the corresponding letters accented showing the corresponding parts in the middle or complete diagram.

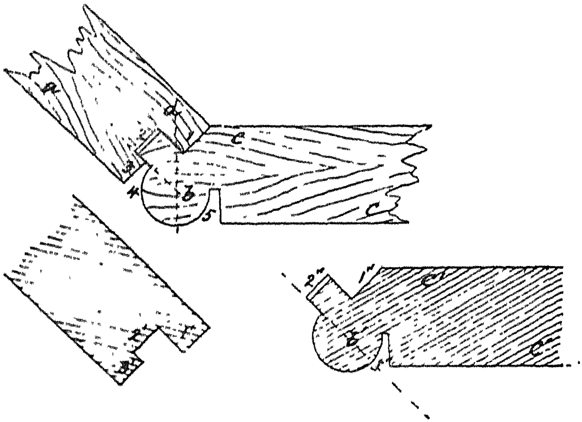


Fig. 50.

Joints for Pieces Circular or Round in Section.

In figs. 52 and 53 we illustrate methods of joining round pieces

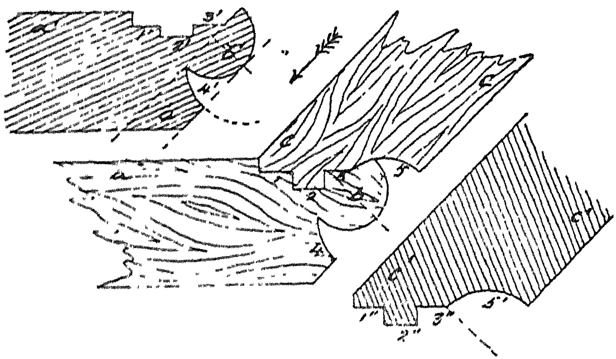


Fig. 51.

of wood together. In fig. 52 the one piece at *a b* has simply a part cut out of an angular form, as at *h i j*, in vertical section at one side; the end of the other piece *c d*, *f e* is cut to the same angle and

with the same length of face as *h i j* and inserted. The two are kept together by glue, or are nailed. The lower diagram gives an inside view or plan view of the part *c e f* cut out in *a b*.

In preceding chapter we gave in fig. 52, p. 91, one method. In fig. 53 a more secure method than that shown in fig. 52 of joining two round or cylindrical pieces is illustrated. In this the angular part *a b c*—side view—is not cut out right across the piece, but only to a certain depth on each side, leaving a central diaphragm, tenon, or tongue *d* in the centre of the angular cut. The end of the other piece, *l*, is cut to the same angle as *a b*, *b c*, at *i j*, *i k*, but is provided with a groove or open mortise, *i*, into which passes the tongue or tenon *d*. The central diagram at top, *h g*, is a cross section of piece to the left on the line 1 2; the lower diagram to left shows a front

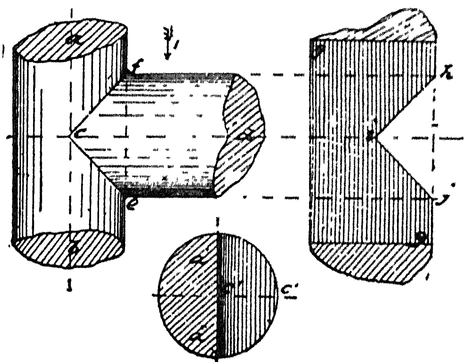


Fig. 52.

elevation or side of piece *a b c d* when looked at in the direction of the arrow 2; *d′* being tenon or tongue *d*, the line *b* 2 being that in which the two sides *a b*, *b c* meet at point *b*. In another modification of this joint, the angular piece is cut out as before, as at *a b*, *b c*, upper diagram to the left, but a square mortise is cut out at the back to the depth and position shown at dotted lines *a n*, *c m*. This mortise is shown at *u u* in the lower diagram to the left, and as seen when looked at in the direction of arrow 2. In this case the end of the other piece is cut off at each side to the same angle, as shown at *o q*, *q p*, but a tenon or tongue is left in the centre of which the outer edge is at *m′ n′*, *m′ n′* being equal to the diameter of the rounded piece. This tenon or tongue is shown in plan as seen when looking down upon side *o m′* in the direction of the arrow 1 at the diagram to the left at *r*, *o′* and *p′* being the sloping sides of angula

shoulder or butting faces. The end views of those two last described diagrams, as seen when looking in the direction of the arrow 2, are at *v v* and at *y y*, *x x*.

General Work of the Joiner—Panel Work.

Before proceeding to that important part of the work of the joiner

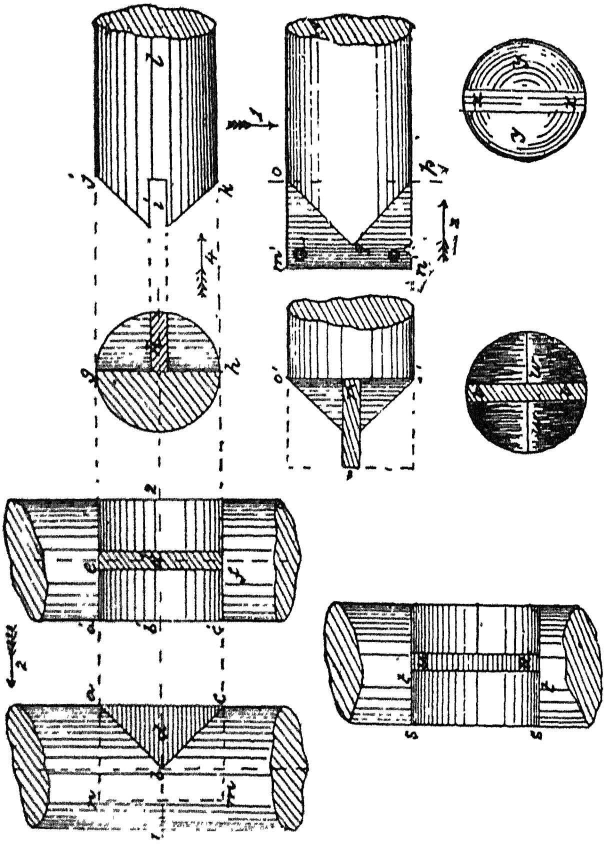


Fig. 53.

—the framing of doors and windows—we shall take up and illustrate various forms of joints and of framing work which have a more or less direct connection with those essential parts of the fittings of a house. These preliminary illustrations cannot always or easily be

grouped under distinct divisions; still a general classification, useful for most purposes of reference, may be attempted. The first we shall take up will embrace general panel work. "Panels" may be defined as parts marked off by some peculiarity of position and formation, as distinct from the general body of a framing, or framework, or a boarded surface. Usually the "panel" is placed in relation to the general surface of the framing by which it is surrounded, so that its surface is sunk, so to say, below the surface of the frame; in some cases, as we shall see, the panel is raised above the surface of the surrounding framework. When there are several panels in a piece of work, as in a door, they are usually placed symmetrically in relation to the framing, generally in pairs alongside of each other, and there may be two or three sets of those pairs in the framing. In other work they may be ranged in line at the same height, and at certain distances from each other. Panels are used in a wide variety of work, such as in doors, window shutters, staircases, and in the decoration of walls or parts of walls. (Illustrations of panel work under those heads hereafter.) This panel work will be found illustrated in figures 1 to 7, Plate XXIX., and in Plates XXX. and XXXI., Joinery.

Square Panel.

In fig. 2, Plate XXIX., Joinery, we illustrate a "square" panel—to $\frac{3}{4}'' = 1$ ft. scale—in cross section at top on the line 1 2 in the elevation below. In this *a, a*, are the "styles" or side bars of the framing which are shown in elevation at *c c*, with cross-bar called a "rail," *d d*—in lower diagram elevation—the framing enclosing the panel *b b*, which is let into the styles *a a* in the centre of their thickness; thus leaving square recessed parts in each side: hence the name "square panel." The diagram to the left of lower drawing is a vertical section on line 3 4 showing the cross-bar *d'*, corresponding to *d d*, *c' c'* style, *e' e'* panel.

A Flush Panel.

In fig. 1, Plate XXIX., we illustrate a "flush panel"—so called because *one* surface or side of the panel *c c*, in cross section at top on line 1 2, in drawing at bottom (scale same as fig. 2, Plate XXIX.), is flush with the surfaces of the styles *a, b*. In the front elevation, *d d*, *e e*, "styles," *g g* "top rail," is the framing enclosing the "panel" *f f*. The diagram to the left is a vertical section on line 3 4, showing panel *h h*, style *i i*, "top rail" *g g*.

Raised and Moulded Panel.

Panels of the ordinary kind or cheap class are perfectly flat in surface, as at *b b* in fig. 2, or *c c*, fig. 1, Plate XXIX. But in the

better class of work the panelled surfaces are ornamented by raised parts and by mouldings. In fig. 2, Plate XXIX., we illustrate in the upper drawing a cross section of a "raised and moulded" panel, the raised part being from *b b* to point 4 in centre, in larger scale at *g h*; the flat part, as at *f* or *c c*, is called the "margin," and it is separated from the "raised" part of the panel by a "moulding" at *e*. The panel is let into the styles *d*, *d*. The second diagram represents another form of "raised" panel, with "margin," but no moulding. In this the part *a b* is raised above the "margin" *c c*, as shown at *j*, *i* being the margin and body of panel. The lower diagram below to the left is elevation of the moulded and raised panel *f e h g*, in section above, and *i' i' j' j'* elevation of *i j*.

Moulded Styles enclosing Panels—Bead Flush.

The styles are sometimes ornamented with a "moulding" worked on the side or edge nearest to and extending in length from top to bottom of the panel. This is shown in fig. 4, Plate XXIX., in which *a a* is a square panel let at *b* into the style *c*, the edge of which is shown moulded as in front elevation at *d*. This is more completely shown in fig. 5, Plate XXIX., in which the upper drawing is a cross section of style *b b* and panel *c c*, *a a* showing the "moulding" worked on the inner edge, *a a*, of style. The part elevation is shown in lower diagram, *d d* being the style moulded in margin, *e e* the "flush" panel. This arrangement is technically termed a "bead flush" panel.

Bead Butt Panel.

In the arrangement called "bead butt" the moulding is worked upon the "panel," not upon the "style" as in fig. 5, Plate XXIX. This is illustrated in fig. 7, Plate XXIX., in which *a a* shows the "style" with groove *b*, into which part of the "margin" of the panel (see fig. 3, Plate XXIX., at *f f*) which forms the tongue is inserted; *e e* shows the moulding worked upon the panel *d*. The lower drawing in fig. 7 gives elevation, showing the mouldings of cross section marked 1, 2, 3, etc., in front elevation. In this *f f* is the cross-bar or "rail," *g g* part of the "style" of framing which encloses the panel. In the arrangements illustrated in figs. 5 and 7, Plate XXIX., "bead flush" and "bead butt," it will be seen that in the finished work the panel shows as ornamented or "margined" with the moulding at the side only. In the "bead butt" arrangement, in fig. 7, Plate XXIX., while the moulding can be worked along the length, or in the direction of the grain of the wood of the panel, it could not be worked across the breadth or against the grain (see "Grain" in "The Cyclopædic Dictionary of Technical and Trade Terms") of the wood. The moulding at the two sides of the panel—one of which

only is shown in lower diagram in fig. 7, Plate XXIX.—stops short therefore at the point where the panel joins the cross-bar or rail *ff*. Again, the same peculiarity is shown in the panel work known as "bead flush," illustrated in fig. 5, Plate XXIX., in which the moulding, as *a a*, is worked on the margin of the "style" *b b*. For although the moulding might be worked on the lower edge of the rail, as *ff* in fig. 7, Plate XXIX., the grain of the wood running rightly in the direction of the length of rail, the young joiner will perceive that the moulding on the inner margin of the "style," and that on the lower margin of the "rail," would not meet properly—that is, could not be made to "mitre," so that there would be a break at the corner where

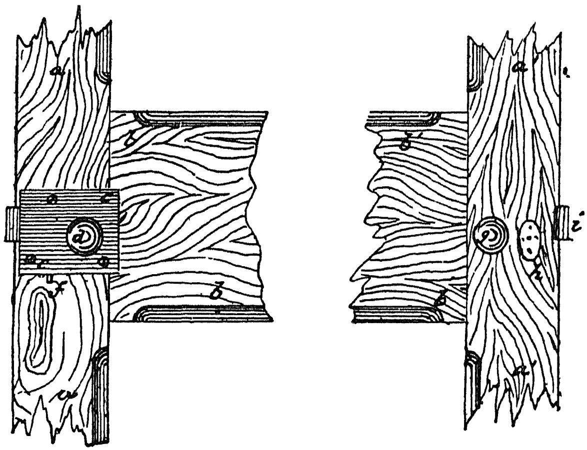


Fig 54.

the vertical moulding or margin of style and horizontal moulding or margin of rail approached each other.

"Stuck-on" Mouldings in Panel Work.

Where, therefore, a panel is to be surrounded on all sides with mouldings, at top and bottom as well as at both sides, the arrangement known as "stuck-on mouldings" with "square flush panel" is adopted.

The arrangement known as "stuck-on mouldings" and "flush panel" is illustrated in fig. 6, Plate XXIX., the upper diagrams to the left showing in section and in front elevation in the lower drawing the stuck-on mouldings for a "flush panel" (see fig. 1, Plate XXIX.), and the opposite drawings to the right in same relative positions the

stuck-on mouldings for a "square panel"—that is, with sunk or recessed faces (see fig. 2, Plate XXIX.). In both cases in fig. 6 the moulding is worked in separate pieces, and cut to the requisite lengths to reach from end to end and from side to side of panel; the four pieces—two sides, and one top and one bottom piece—"mitring" at the corners, as shown in the lower diagrams at *h* and *i*. Where a "flush panel" is employed, as at *b b* in upper diagram to the left, *a a* being the style, the inner surface of which is flush with inner surface of panel *b b*, the moulding *c c* is "stuck on" so as to cover part of the surfaces of both style and panel, as shown. Where a "square panel" is used, as *d d*, to the right, with a recessed or sunk surface below surface of style *e e*, the moulding is "stuck on," or secured to the panel only; the top and side mouldings "mitring" at the corners, as shown at *i*; *j j* is part of the "style," *i i* of the "top rail."

Chamfered Styles with Square Panels not Moulded.

When "square" panels are used, and the work generally plain or cheap in style, no mouldings are given either to the styles or panels, as in the arrangements illustrated in figs. 3 to 7 inclusive, in Plate

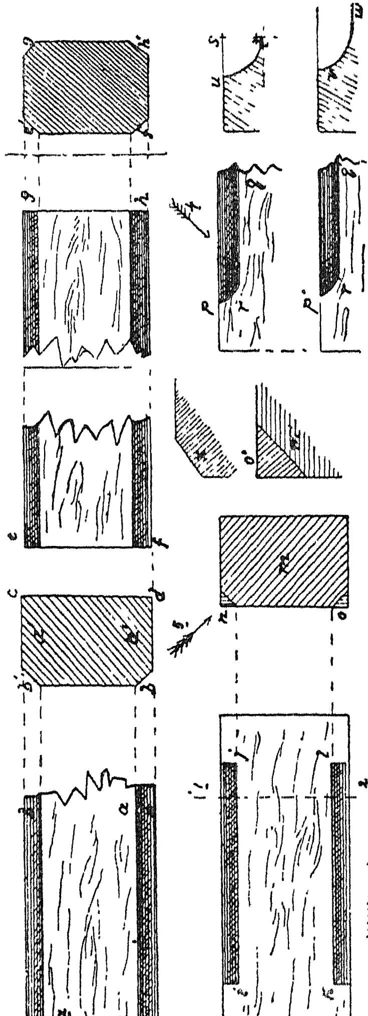
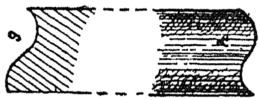


Fig. 55.

XXIX., but some degree of ornamentation is secured by chamfering the margins of the "styles" and the "rails" at sides and at the top and bottom of the panel, as shown in fig. 54. In this *a a* in the diagram to the left is the "lock style" of a door, *b b* the "lock rail"; the other side of this outside the room being shown at *a′ a′ b′ b′*. When we come to the subject of doors, their different forms, details of construction and fittings, we shall again refer to this diagram, giving it meanwhile simply to show the mode of ornamenting the panelled part, with cutting the corners or margins nearest the panels of the styles, as *a a*, and "rails" as *b b*, as shown by the shaded parts.



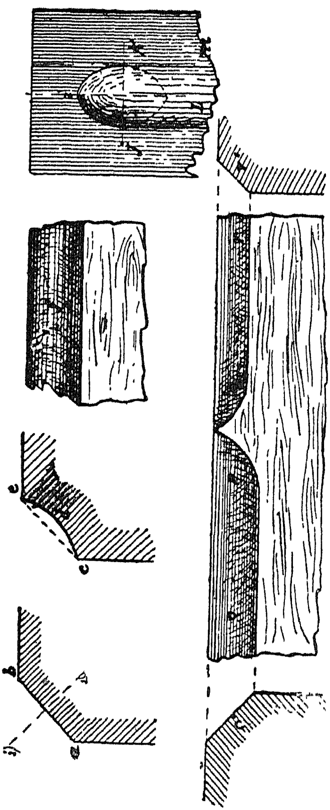


Fig. 56.

Flat Chamfers—Stop Chamfers—Chamfered Work—Varieties of Chamfers.

This will be an appropriate place to illustrate the kinds of "chamfers," and also some points connected with panel work not yet noticed. In fig. 55 we illustrate at *a a b b* in elevation what is called a "plain chamfer." This is simply taking off the "arrises" or corners at one of the faces *a a*, as at *b b*, shown at *b b* on inner corners of piece *a′ a′*. When the other face, as *c d*, is left square, the chamfer is called a single plain chamfer. When both faces are chamfered, or all the corners, as at *e′ f′ g′ h′*, are cut off in elevation at *e f g h*, the chamfer is called a double, or double-faced plain chamfer. In the plain chamfer the bevelling is done along the whole length of piece, stopping only at the ends, as *e f g h*.

What is called a "stop chamfer" is that in which the bevel or taking off of the corner or arris does not extend along the whole length of the piece, as in preceding diagram, but stops short near one end, or near both ends, as at *i j k l* in fig. 55; cross section as on line 1 2 looking in the direction of the arrow 5, as at *m n o*; *o'* shows the shoulder or end at *n* formed by cutting off the chamfer square at the ends; at any part between *k* and *l* the corner or chamfer shows as at *x*. In place of cutting off the end of the chamfer square as at *j* or *l*, giving a flat shoulder as at *n* and *o'*, the chamfer is run up to meet the edge, as at *p*, by a curve, as at *r*. This curve may be sharp, like the quadrantal curve as at *s t u*; or flatter, as at *v w*.

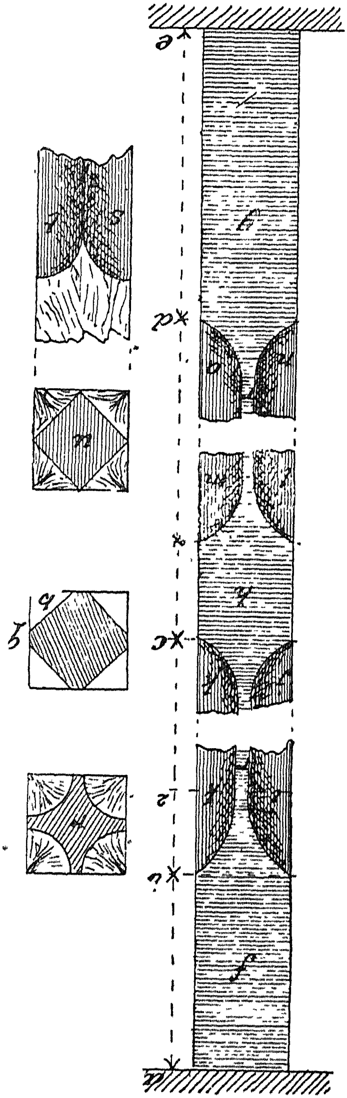


Fig. 57.

Work continued.—Curved Chamfers.

In place of the face of the chamfe or bevel being flat, as shown in section at *a b*, fig. 56, it may be curved, as at *c d e*, front or side elevation of which is at *f*; *g* shows another section of a chamfer face, more easily made when the chamfer is a plain, not a stop chamfer; *h* is side view of *g*. The front view of a stop chamfer, where it terminates near the end of the piece, is shown at *i j k l m*. A piece may be stop-chamfered with chamfers of two different sections, as *o p* of section as at *o'*, and smaller stop chamfer *q r* section at *r'*. It may be as well here to give illustrations of a rail, such as that of

a staircase or a railing enclosing the well hole of a staircase at side of landing. In fig. 57 we give at *a e* elevation of rail square at ends, at base or lower part *g*, at top or upper end at *f*, and in the centre *h*; the heights being, *e* to *d*, 6 inches, *d* to *c*, 11 inches, *a* to *b*, 11 inches, and *b* to *a*, 4 inches. The stop chamfers are at each corner, *i j*, *k k* being two contiguous ones. These are cut deep, so as to leave but very narrow parts or faces, as at *q* and *r*, between the two chamfers, the faces of the chamfers being flat, as at *p q*, or they may be curved as at *r* (section); the chamfers, as *s t*, may be cut so deep that they meet at a sharp or knife edge, as at *s* and *t* on the line *t*, shown in cross section at *u*.

Different Forms of Panels.

We conclude this part of our paper by giving some illustrations of panels. In fig. 1, Plate XXIX., we give a "flush" panel for a front or entrance door, in which in front elevation *a*, *b*, are the two rails, *d d*, *e e*, the styles, *c c*, *g g*, the panel with stuck-on mouldings all round and mitring at corners; *g h* is a vertical section in line 3 4. In this the recess between the style and panel is one side only. Where there are recesses on both sides of the panel *b b*, fig. 2, Plate XXIX., and the styles *a a*, the panel is known as a "square" panel. In this figure the lower diagram is front elevation, that on the left is a section on line 3 4. In fig. 3, Plate XXIX., we illustrate different forms of panels. In the upper diagram, *a a*, the styles, carry one "square panel," which is not flat, as in fig. 2, on the inner side, but tapers to the centre, which is thickest to the sides, where it may be either square, as at the right hand, or finished with a moulding, as on the left.

Resuming our description of the drawing named in preceding paragraphs, the second diagram shows a "flush panel," with styles *d d*, the panel having a raised position in the centre, as shown at *a b*, with flat spaces, as at *c c*, all round. The lower diagram to the right is an enlarged view in section and elevation of the part of the panel of upper diagram to the right. The lower diagram to the left is an enlarged view of the left-hand side of the panel, which is technically called a "raised panel." Figs. 5 and 6, Plate XXX., are other views of raised panels; and diagram B in next figure, 58, shows a form of panel in the Gothic. Other forms are illustrated in figs. 1, 2, 3, 4, and 6 in Plate XXX. In fig. 3, Plate XXIX., the flat part of the panel surrounding the raised central part is called the "margin" (see also fig. 5, Plate XXX., at *b*). The panel, as in fig. 3, Plate XXIX., is called a "moulded raised panel" when there is a moulding at the margin, as *f e h*. There are other distinctions in panel work yet to be

noticed. In "flush panels," as in fig. 1, Plate XXIX., the "moulding" or "bead" is worked only on the two sides (vertical) of the panel, as at *d d*, fig. 5, Plate XXIX., and these terminate at the rails, as *f f*, no moulding being at the ends of the panel. This is called "bead butt" panel. When the panel has mouldings all round—that is, at top and bottom as well as at the sides—the mouldings meet at the corners, and are mitred, as shown in the lower part of the diagram

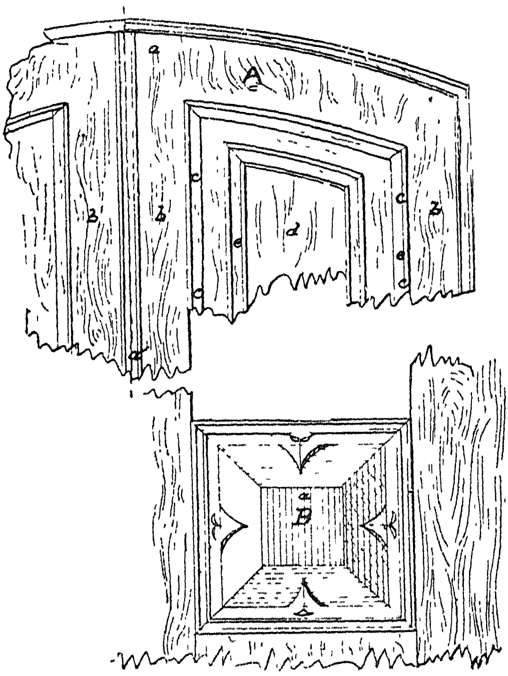


Fig. 58.

in fig. 6, Plate XXIX.; this is known as a "bead flush" panel. In panel work where a moulding is worked out of the solid, as at *b* in fig. 4, or at *a a* in fig. 5 of the style, as *c c* or *b b*, the term "stuck on" (a corruption of "struck on," which is the true term) is applied. This is only applicable to "bead and butt" panel work vertically, as the mouldings would not mitre if struck horizontally on the rails. When the mouldings are made separately and nailed on to the styles

j j, and rails *i i*, fig. 6, Plate XXIX., they are called "laid on" mouldings. They may be nailed on either to the styles and rails or to the panels in "flush" work, or all round the panels in "square" panels. In fig. 58, in diagram A, we give a panel at upper part of door, in which the upper rail *a a* is curved at top, *b b b* the styles, separated in

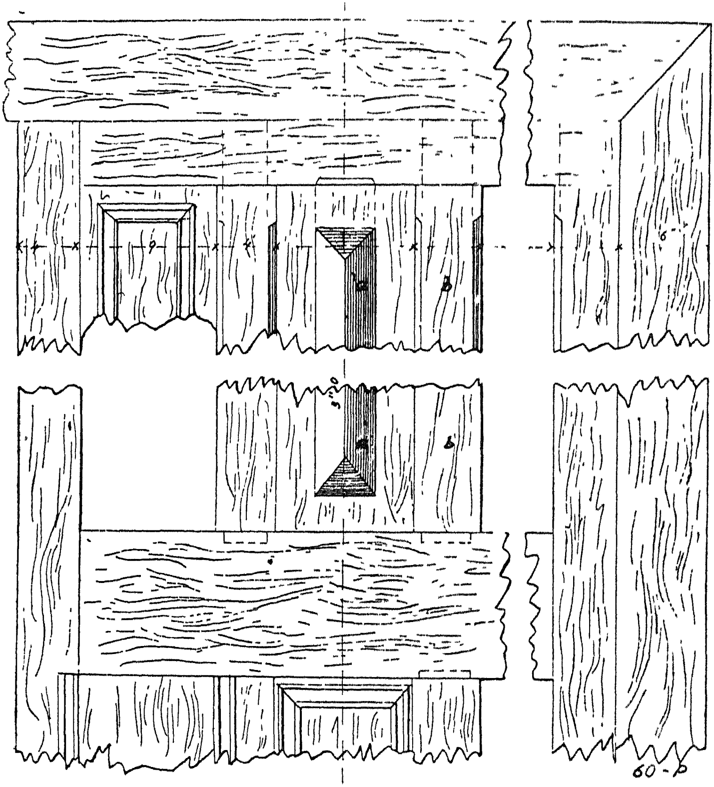


Fig 59.

the centre by a moulding *a a′*; *d* the upper panel, with stuck-on mouldings *c e e*. Diagram B is front elevation of lower panel. In fig. 6, Plate XXX., we give a section of middle style and panel; the middle style *b b* being provided down the centre with a stuck-on moulding, as at *b a*, corresponding to the vertical moulding *a′ a′* in fig. 59. A moulding as at *c c* is worked in the margin of the style,

corresponding to *c c* in fig. 58. *e* shows the moulding in section stuck on the square panel *f g*, the margin *f* being in this way wide. In fig. 59, and in figs. 1, 2, 4, and 6, Plate XXX., we give illustrations of panel work, and in fig. 3, same plate, section and elevation of mouldings for a panel.

Joiner's Work in the Construction of Doors.—Different Kinds of Doors.

We now come to illustrate the different forms of doors, and various details of their construction. Doors are either external or

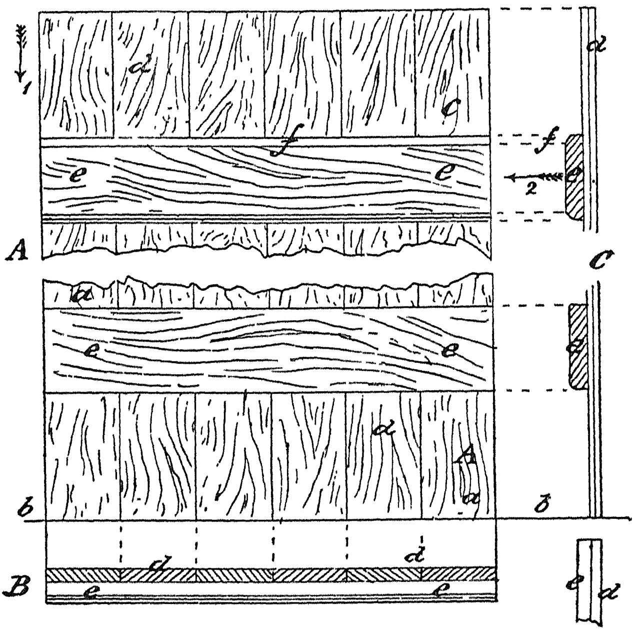


Fig. 60.

internal, and both may be constructed much in the same way. The chief difference between them, if difference may be made at all, is that external doors are heavier in their timbers—that is, thicker and broader—and are not quite so much ornamented with mouldings, or so highly and carefully finished, as internal or private room doors. Doors are of different classes, beginning with those adapted either for houses of a simple character, or for out-buildings, etc., where economy is carefully studied, and going up to the more elaborate forms, used in houses of the higher class.

The "Ledged" Door.

The simplest form of doors is shown in part elevation at A, fig. 60, in plan at B, looking down in direction of arrow 1, in C side elevation or edge view looking in direction of arrow 2. This form is what is called a "ledged door." In elevation in diagram A, the lower part is *a a*, next to floor or ground line *b b*. The door is made up of flat planks, *a a c d d*, running vertically from foot or floor or ground line *b b* up to head. These are either laid as in plan B in the cheapest

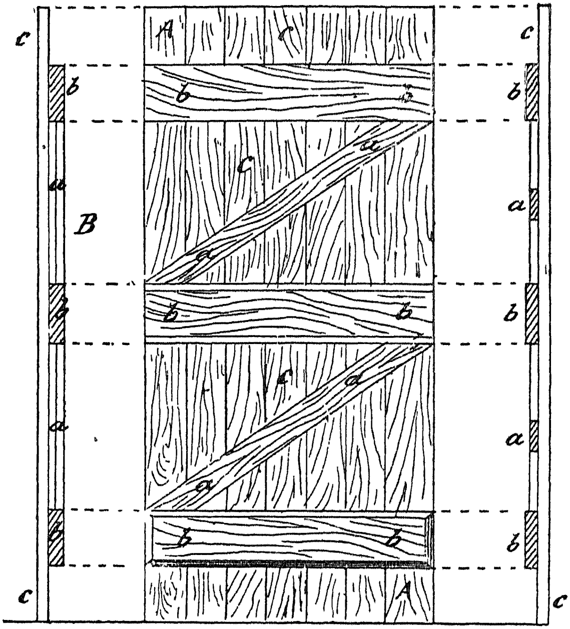


Fig. 61.

class of work, edge to edge, and held together by cross-pieces or bars *e e*. In better work, these and the vertical parts *d d* are secured by joints of different kinds (see preceding paragraphs on joints used in joinery). In the section C the cross-bars *e* are simply laid flat and nailed to the upright planks *d d*. The edges of the cross-bars *d d* may either be left square, or have the lines or corners planed off or "chamfered" or bevelled off (see succeeding paragraph), as at *f f*.

Ledged and Braced, and Ledged, Braced, and Framed Door.

Fig. 61 is an elevation in diagram A of a "ledged and braced" door. To the vertical and cross bars of the simple form in fig. 60, the diagonal "braces" *a a a a*, corresponding to the struts of a roof truss, are introduced; these butt against the cross-bars or "ledges"

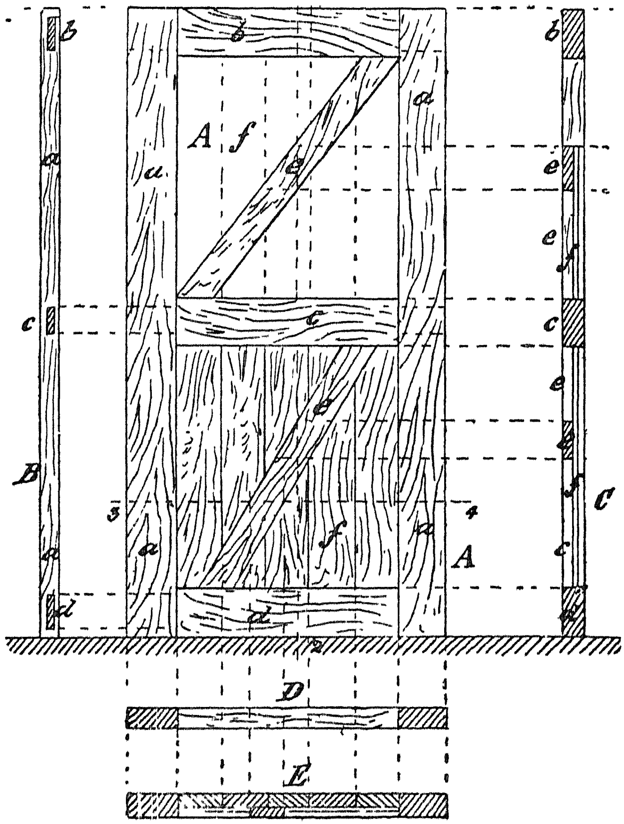


Fig 62

b b b b, while behind are the vertical boards *c c c c*. Diagram B is side elevation or edge view, and C vertical section. A still higher class of door is the "framed, braced, and ledged" door in fig. 62: here, as in elevation in diagram A, we have an outer frame of

vertical pieces, held together and secured by the cross-bars *b, c, d*, the ends of these being tenoned into the styles *a a*. The central spaces are filled with braces *e e*, and the vertical boards *f f*. Diagram B is vertical section on line 2, and C is edge view, showing ends of tenons of crossbars *b, c, d*; D is plan of top edge, looking down; E is cross or horizontal section on line 3 4 in A.

Panelled Doors—Names and Offices of Different Parts—Styles—Rails—Mortises.

The transition from this form of door to the highest class, the "panelled door," is easy and natural. We have seen in the simplest door, as in fig. 62, the absence of the triangular disposition of timbers, which is the element of the "truss," and which gives the strongest form attainable. In this view the panelled door, as in elevation in A, fig. 63, is not so strong as the form in fig. 62, from the absence of the diagonal braces, as *e e*; but those, if required in a door such as an external one, where strength is an object, can be dispensed with in interior doors, which are always panelled in good houses. Elegance or neatness of arrangement, with such ornamentation as mouldings, etc., can give, are what are looked for. In fig. 63 the external framework enclosing the panels is made up of two side vertical boards, *a a, b b*, varying in thickness from 1½ to 2½ inches, and in very superior work even 3 inches. These boards are called "styles"; that by which the door is hung to the casing, secured by hinges, is called the "hanging style," as *a a*; that to which the lock is secured the "lock style," as *b b*. These styles are held together by cross-bars called "rails," of which *c* is the "bottom rail," *d* the "top rail," and *e* the "middle or lock rail." The central vertical bars, as *f f*, are called "muntins" (a corruption of mountings). The assemblage of boards thus arranged leaves spaces, as *g, h, i*, and *j*; these are filled up with the panels, as *a, b, c*, and *d*, in fig. 64, which is the elevation of a *four*-panelled door. There are also six-panelled doors. Generally the panels are nearly equal in length, but in some the lower panels are short, the upper being longer. Fig. 2 and 4, Plate XXX., illustrate outside doors in Continental style. The panels are secured to the framing by grooves, as shown in preceding figures, and as further hereafter illustrated, and are ornamented with mouldings, as explained. In fig. 63, diagram C is the vertical section; B edge view of style *b b*. In fig. 64, B is plan of top edge of door. The rails are secured to the styles by tenons, sometimes single, but more frequently in good work by double tenons, as in fig. 65, in which A is front elevation of rail, *a a, b c*, two tenons. Diagram B is part of style *a* cut vertically in two to show the seats of the mortises *b* and

c; diagram C, end view of rail. In left-hand diagram in fig. 5, Plate XXX., is elevation of part of "lock style," *a a*, and "lock rail," *b*, of a bedroom door, with simple lock, *c*, known as a "rim lock." In diagram B, part of the "hanging style," *a a*, of this door is given in elevation, *b* part of "top rail"; a portion of upper "hinge" is shown at *c*. Diagram C is edge view. The inner edges of styles, rails, and mortises are generally, in good work, "stop-chamfered," as at *d d*, or

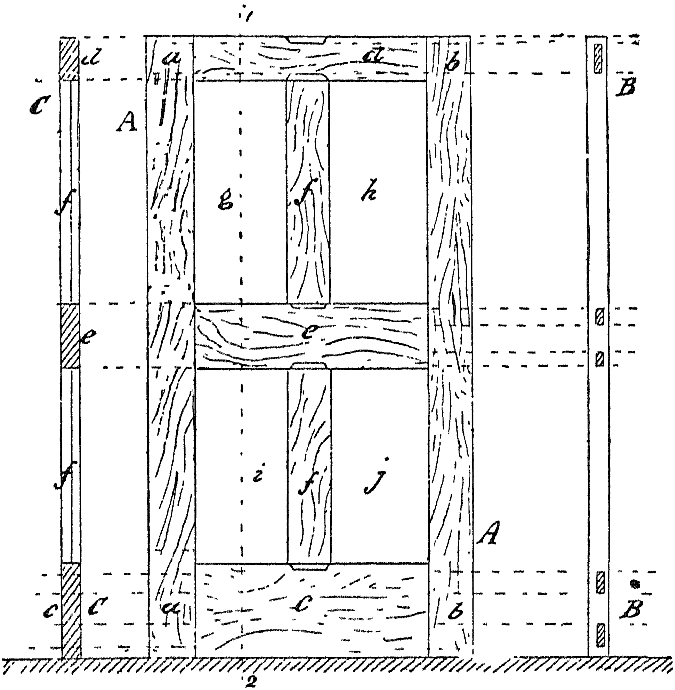


Fig. 63.

bevelled off from end to end, as at *e f*, the two edges meeting in a "mitre," as shown. The "stop-chamfer," *d d*, is the neatest, stopping, as it does, short of the end. A rim lock is screwed on to the outside of the lock style; what is called a "mortise lock" is employed in superior doors, where the lock is to be concealed, nothing but the handle and keyhole being visible; the lock being inserted in the mortise, or vacant part cut out in the style to receive it. Fig. 54

contrasts the two locks. *c d* is the rim lock. In the mortise lock nothing but the handle, as *g*, is seen, and the escutcheon, *h*; *i* is the bolt of the lock; *a a*, *b b*, *a′ a′*, *b′ b′*, are the chamfered styles and rails.

Door Casings.

Doors are secured to "casings." These are of timber, and built into the wall, and are secured to wood bricks or grounds. Fig. 66 illustrates in part elevation an outer "door casing." The sides *b b*, *c c*, are called "jambs," *f f* the "head," into which the jambs are tenoned, the feet being also tenoned, at *d*, into the upper part of stone step, *a a*. Fig. 1, Plate XXXI., is sectional plan showing arrangement and relative positions of various parts of a door and its casing. The door, *l l*, is hinged to the "jamb" *b*, this being secured to the "ground" or "wood brick" *a a*, built into the wall *b b*; *c* and *j* are the "architraves." The opposite "jamb," *f f*, is rebated as at *m*, to allow of a space into which the door "lock style" falls, as shown

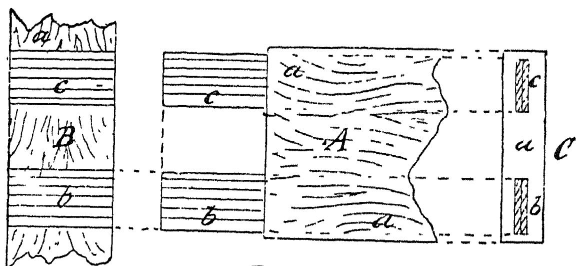


Fig 64.

by the dotted lines, which represent the lines of the door. The outer edge of jamb may be left plain, but is often finished off with a "quirked bead," as at *j*; *k k* hinge. The inner and outer architraves are at *c* and *j*; *a a*, the wood brick; *b*, the wall; *e*, *i*, are the elevations of the architraves, *d* and *h*. The elevations of these two parts of sectional plan of door fittings are given in the under part of the drawing in fig. 2, same Plate (XXXI.). The edge of the door *a*, as looking at it from the inner side, is shown at *p p*, *q q*, being the ends of the tenons of top rail (see fig. 65); *r r*, the hinge; *n n*, front view of architrave; *o o*, the wall, in the void of which the door is hung. In the under drawing to the right, part of front surface of door is shown; *s s*, the architrave; *t t*, the wall.

Joints of Styles and Rails in Panelled Doors.

In figs. 3 and 4, Plate XXXI., we give illustrations of methods of join ng rails and styles, or rails and mortises. Let *a b c d*, fig. 3, be

the style, with moulding stuck on edge; *f g h* is part of the rail, with tenon *f*, shown by dotted lines in style *a b c d*. Front view of tenon and face of mitre of chamfer at *p*, looking at *a b c d* in the direction of arrow 1, is shown in the lower diagram at *k′*, *p′* and *e″*. The section of part *f g* looking at its end, in direction of arrow 2, is shown at *l m n*; the section of a moulding is in this at *e′*. In lower diagram

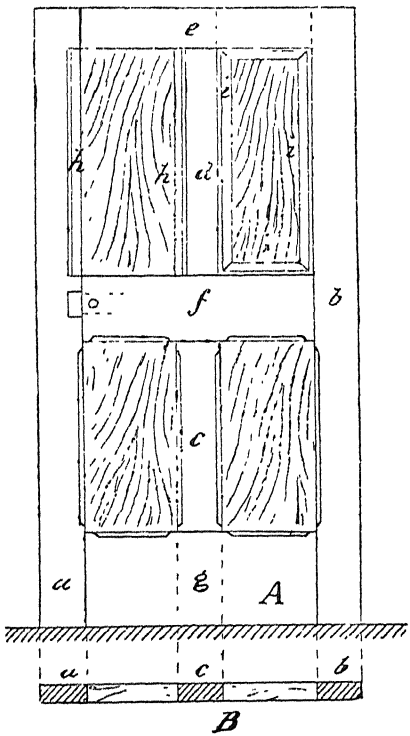


Fig. 65.

to the right is given a view of under side of rail *f g*. In fig. 4, Plate XXXI., *a a* is front view of part of style with moulding worked on edge, at *b b*; part of rail is at *c′ c′ d*. The angular face of part cut out in style *e f*, *f g* corresponds with angular end *h i j* of rail, but a tenon *i l k* is left on, or is inserted in end of piece *c′ c′ d*. The end

view of the style *a a*, looking at it in the direction opposite to that of the arrow 3, is shown in the middle diagram to the right with corresponding letters accented, showing corresponding parts. The line *i″ i″* corresponds to the line at point in rail *c′ c′ d d*. The plan of under side of rail *c′ c′ d* is shown in diagram immediately below *k′*, *l′* being edge view of tenon *k l*. The finished joint is shown at *o o*, *p p*; the diagram below to the left being cross section to the line 1 2. Enlarged elevation *q*, and section *r* of moulding *b b*, or *b″* is given in the two diagrams to the right at bottom of drawing. Another method of forming the junction is shown in the middle diagram at

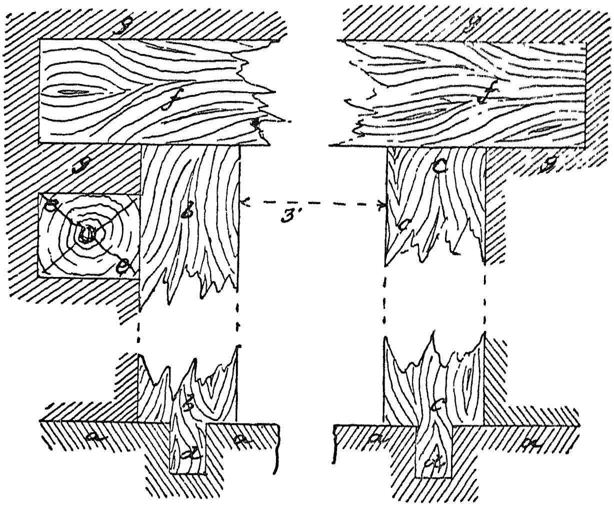


Fig. 66.

the foot of fig. 4, Plate XXXI., the shaded part showing form of tenon with the ends of moulding united.

A Four-Panelled Door.

In fig. 1, Plate XXXII., we give a drawing—to a scale of $\frac{1}{8}$, or $1\frac{1}{2}$ in. to the foot—of a four-panelled interior or room door; showing all the leading parts of the framework, with the exception of top rail, which is usually about half the breadth or depth of the middle or lock rail, marked *b b* in the drawing. The panels are not shown, but the dimensions of the spaces they occupy are given. The panels are plain "square," the only ornamentation in this example being a

"stop chamfer" worked on the margin of styles and rails, as shown at *g g* and *h h*. In the drawing *a a* is the "bottom rail," *b b* the middle, or usually "lock rail," as it carries the "mortice lock," the handle of which is shown at *j*. The "key hole" is covered by a movable part, hung or jointed at upper end, called the "escutcheon," or more frequently in technical talk the "scutcheon" or "skutcheon," shown at *k*. The styles are at *c c*, *e e*, the style *c c* termed the "lock style," being that in which the lock is mortised. The style *e e* is called the "hanging style," being that on which the door is "hinged" or "hung" to the door casing. The vertical pieces, or "muntins," which divide the panels from each other, placing them in pairs on each side of the door, are shown at *d d*. The door framing thus constructed is surrounded on both sides and at top by the architraves *f f f*.

Architrave of a Four-Panelled Door.

The section of architrave in relation to the door casing or check is shown in upper diagram to the left in fig. 2, Plate XXXII.; *a a* being part of the door casing; *b b*, the section of architrave, of which part elevation is shown at *c c*, 1, 2, 3, and 4 showing similar parts in section correspondingly lettered. The edge view of the "lock style," as *e e* in fig. 1 preceding, is shown at *d d*; *e e* shows the brass plate let into the edge and secured by screw nails as shown. This is part of the lock furniture of the door, *f* indicating position and section of the shooting or locking bolt of the lock, which passes into the aperture of a brass plate secured to the inner side or edge of the door casing. The bolt, which secures the door, being closed—not locked—*f* being the locking bolt, is shown at *g*, this being worked by the handle *j* (see fig. 1, Plate XXXII.), of the lock. The part of the lock furniture attached to the door-casing opposite to the edge, as *d d d*, of the door style, is shown in the lower diagram to the right. The part 3 3 in this corresponds to the face of the recessed or rebated part *p* in drawing above, cut in the face of the door casing *n n n*; the door passing into and resting against the face of recess or rebate *p*. In the upper diagram to the right, *o o o* is the outer architrave secured to the door casing *n n n*, *r* part of the inner architrave. The part of the lock furniture secured to the door casing is shown at *t t*; it is a brass plate let into the face *g*, or 3 3 of recess or rebate *p*. The aperture in this into which the bolt *f* of the lock passes is shown at *v*; that into which the bolt moved by the handle *j* passes, is at *u*; a spring *w*, cast on to the plate *t t*, being shown at *w*. A small projecting part as *w'*, to make the opening and closing of the door more easy. The two diagrams to the left at lower part or drawing show the elevation *k l m*, the chamfered part of framing with section at *k' k'*

line 1 2 in fig. 1, Plate XXXIII. Fig. 4, Plate XXXIII., is part vertical section at bottom of fig. 1, same Plate, the scale to which this is drawn being one inch and a half to the foot. In fig. 1, Plate XXXIII., *d d* is floor line, *e e* "skirting board," *e′ e′* wall space between this and "window sill" *f f*, *g g* the architrave, surrounding the opening on three sides, *h h* the middle bar, or properly speaking the upper cross-bar of lower sash frame. The sheets or sashes are formed of bars tenoned into one another in one or other of various ways.

In vertical section, fig. 4, Plate XXXIII., and in horizontal section in fig. 2, Plate XXXIV., the letters of reference are the same, and indicate the same parts; the other parts, not seen in either one or the other, are as follows: beginning with fig. 2, Plate XXXIV., the sash weights, *i i*, are inclosed in a species of box extending from top to bottom of window opening, of which box, so to call it, *j j* is the "outside lining," *k k* the "back lining," *l* the "inside lining," *m m* the "pulley style," *o* the "parting slip," and *p* the "parting bead." In the frame of the upper sash *a a*, fig. 1, Plate XXXIII., of which *a* is the side bar, *q*, fig. 2, Plate XXXIV., is the pane of glass; and in frame of lower sash, of which *b′* is the side bar, *r* is the pane. In fig. 4, Plate XXXIII., the same letters of reference as in fig. 2, Plate XXXIV., indicate the same parts; but *s s* is the stone window sill, end *t* of which is outside, *u u* wall, *v v* "reveal" of window opening. Fig. 4, Plate XXXIV., is plan of top of lower sash *b b*; in elevation, fig. 1, Plate XXXIII., *a a* is the top of upper bar of sash frame, *b b* side bars, *c c* the finger "bowls," or lifting hooks (finger "rings" are sometimes used), by which the sash is lifted. In fig. 4, Plate XXXIII., *x* is position of window-blind rack and pulley, the window-blind roller studs being placed vertically above *x*. In fig. 2, Plate XXXIV., the cord to suspend the sash weight *i* is placed in a groove—a black dot—in the side bar *b b*, as at *y o*. Fig. 5, Plate XXXIV., is elevation to same scale as fig. 4, Plate XXXIII. is drawn—$1\frac{1}{2}$ in. = 1 ft.—of the lower corner in fig. 1, Plate XXXIII.

In fig. 5, Plate XXXIV., is given part elevation of the inner view of window in fig. 1, Plate XXXIII., of which fig. 4, same Plate, is a vertical section. Corresponding parts are correspondingly lettered. The scale for both figures is the same, Plate XXXIII., diagram C, being part of front elevation, and diagram D side elevation of same; in diagram B, *b b* is the glass. In fig. 1, Plate XXXIV., a method of securing skirting-board, *e e*, is shown; this is tenoned into floor joist at *h*, and the skirting-board is secured to "wood grounds" or wood bricks at *a′ a′*, *c′* being the plaster, the lower edge of which passes into a groove, not shown in the drawing, in the upper edge of ground, *a′*.

French or Casement Window.

In fig. 1, Plate XXXV., we give part horizontal section in centre of a casement or French window, the two "lights" or halves of which are hung vertically, opening right and left like the two halves of a folding or double door, and in fig. 3, diagram B, Plate XXXIV., a part vertical section, taken on the line 1 2, fig. 1, Plate XXXV. The vertical side bars of this casement window are seen at *a b* in fig. 1, Plate XXXV., and are rebated, as at *c*, to make a water-tight joint from top to bottom of window. To prevent the water from being blown into the horizontal joint, where the bar *i*, fig. 3, Plate XXXIV., is over the sill *h h*, a "weather board," *d*, is fixed to the sash, this being throated at the lower side—that is, grooved horizontally from end to end to prevent the drip from passing from foot of board to the joint between the sash bars. The weather board is also weathered at upper surface, giving an inclined surface for the rain to slide off, the throating under preventing this from creeping in behind the board, as it cannot cross the groove. This weather board is secured in two halves to the bottom bars and sides of the sheets. To cover internally the vertical joint when the window is closed, the moulded bar *e*, fig. 1, Plate XXXV., is secured to one of the vertical bars or styles, as *a*; the panes of glass are at *f f*, and *g g* is the window sill in the interior of the room. The parts below this are similar to the arrangement in fig. 1, Plate XXXV. Still further to secure a water-tight joint at bottom of casement near the sill, the bottom bar at *i*, in diagram B, fig. 3, Plate XXXV., lies, when the window is closed, against the cross-bar *j*. The bottom bar of sheets may be made still deeper, making the joint all the longer up which the rain has to be blown before it can enter the room: this is shown in diagram A, fig. 3, Plate XXXV., at *h*; *c*, *d*, *e*, *f* and *g* are parts corresponding to those in upper and lower diagram in fig. 1, Plate XXXV. In place of the square rebate *c*, as in upper diagram in fig. 1, Plate XXXV., the meeting vertical joint of sheets is constructed, as in fig. 4, diagram A, Plate XXXIV., at *a b*, covering pieces being outside and inside to conceal the joint and make it externally water-tight. Fig. 4, Plate XXXV., diagram B, is part cross section and part elevation, of inner edge of vertical bar, as at *h* in fig. 1, Plate XXXV. If the sheet be divided either horizontally or vertically by an astragal, the section of this will be as in fig. 4, Plate XXXIV., at B, dimensions and general outline or elevation being as in same figure, diagram above B.

Venetian Windows

are what are called "three-light" or three-sheet windows, but of which the central light, as *a a′ a*, fig. 6, Plate XXXI., is wider than the

two side lights, *b b' b'*, *c c' c'*; the lights are divided by solid piers, *e e*, *e' e'*, in stone, or of flat mullions in wood. In the plan in lower diagram *d'd'* is the wall broken by the three voids. Fig. 3, Plate XXXV., gives in elevation and section part of a mullion or pier, as *e e*, *e' e'*, in fig. 6, Plate XXXI., showing mode of ornamenting them when of wood. Fig. 5, Plate XXXV., shows the method of hanging the sashes, the parts being the same as in this portion of an ordinary sash window: see fig. 2, Plate XXXIV.

Bay Windows

are, like the "Venetian" windows, "three-light"; but in place of having all the three in the same plane or running in the same flat surface of the wall, as in fig. 5, Plate XXXV., have the side lights, as *c c*, *d d*, fig. 7, Plate XXXI., oblique, or at an angle to the central light *a a*, which runs in the same plane as the walls *e e*. The central light *a a* is divided by piers, *b*, *b*, from the side lights, which are shown in the plan forming the lower diagram of fig. 7, Plate XXXI. The mode of fixing the sash-weight boxes, or of hanging the lights from a bay window, is shown in fig. 2, Plate XXXV.; the parts indicated by accented letters forming the part for the central light, corresponding to *a a*,—those not accented the points for the side lights, corresponding to *c c*, fig. 7, Plate XXXI. (See fig. 4, Plate XXXV.)

Bow and "V" Windows.

Bow windows are often considered the same as bay windows, but the distinction between them, which is very marked, is easily remembered. In a "bay" window there are three lights, and the plan forms part either of a hexagon or an octagon, as shown in the plan in fig. 7, Plate XXXIII. In a "bow" window the plan is either semicircular, or part or a segment of a circle less than a semicircle. The form of "V" windows is, as their name indicates, made up of two lights, as *a a*, *a' a'*, fig. 1, Plate XXXVI., placed at an acute angle, and meeting in a sharp end or arris at *c*, *c c* the wall from which the angular walls spring. In the figure the sashes or lights are fixed, not hung as in the windows in fig. 2, Plate XXXIV., and figs. 2 and 5, Plate XXXV.

Window Shutters.

The shutters most generally employed are of the class known as "folding," so called from the boards being hinged together at their edges, and folding in upon one another so as to occupy a much less space than when they are opened out and extended. When so folded up they are pushed back into a recess made in the wall, or provided for by wooden constructions of cases where the thickness of the wall

does not admit of the depth of cases or recesses necessary to hold the shutters. These recesses, however formed, are called "shutter boxes," and when formed in recesses in the thickness of the walls they are lined with wood. The simplest form of shutter and shutter-boxing is shown in fig. 3, Plate XXXIII.; *a a b c* the wall in which the recess is made; *h* the line of window to be covered by the shutter *f g h i*. The back part or board, as *e b*, is called the "back lining"; *d e*, *c b*, the "side linings." Shutters are either plain or panelled, the latter being of course employed in the better class of buildings. There are two shutters or "flaps," as the leaves are technically termed, in the plan in fig 3, Plate XXXIII.—the "front flap," as *g g h*, only panelled, *f* being the "styles" into which the panels are fitted. The "back flap" is at *i i*, and is plain. When the shutters are in place in the box, the front or outside face to the room shows panelled. It may be a square panel flush or flat at back, as shown, or it may show panelled on both sides. Fig. 2, Plate XXXIII., is part elevation of shutter front panelled. Fig. 3, Plate XXXVI., shows shutter-boxing with three flap shutters. In this case the centre flap is called the "second flap," *j j l l m* the front flap, and *f g f* the "back flap." The "back lining" is at *b b*, *c* being ground into the two pieces or styles *b b*. This plan is for a Venetian window. The diagram to the left in fig. 4, Plate XXXVI., shows shutters and boxing for a bay window. Where the boxing is not made in a recess in the wall, but projects from the wall, the side of the box is ornamented with an architrave moulding, as at *i i* in diagram to the right in fig. 4, Plate XXXVI. Where no shutters are used, the diagram in fig. 2, same Plate, shows how the meeting angles of walls from a bay window may be inclosed by a diagonal piece moulded in face. In Plates XXXVII. to L. inclusive we give a variety of subjects to scale illustrative of several departments of Carpentry and Joinery work, the titles and details of which are sufficiently explanatory of their nature and their constructive points.

APPENDIX.

STAIRCASING AND HANDRAILS OF STAIRS.

Introductory.

It has been suggested to us that it would form a useful addition to the matter which has been given in this volume if we devoted some paragraphs to the subjects of staircases and the handrails with which they are in good classes of houses provided, and by which they are guarded. These two subjects have always been those carrying with them points of great interest to the joiner; and many works, some of them large and exhaustive, but all of them pretty intricate and full in detail, have been published from time to time. The department of handrailing especially has had special attention devoted to it. It seeming to be possessed of a species of fascinating interest to many practical men, and being a subject capable of varied treatment, not a few writers have entered the field, claiming each of them to have discovered the true and the best, that is the only way, in which handrails can be most quickly, accurately and economically turned. The subject is too wide, therefore, to admit of our having the space necessary to give it anything like an exhaustive treatment; at the best we can only give a few of its leading points. These will have reference to the ordinary or general method, or what may be called, if one pleases so to designate it, the old-fashioned method; but which, notwithstanding the new methods of working, still maintains its ground. The paragraphs we give are as practically suggestive as possible, and give the young reader a fair idea of what its principles are, and of some methods of doing the work, leaving him to study the subject in special works dealing with it in a way more or less exhaustive. Without further preface, then, we proceed to point out a few of the

Varieties of Staircases.

The first we shall notice is that variety known as a "staircase with landings." Figs. 1 and 2 are the plan and section of a staircase

with a level landing; the dotted lines in the former represent the carriages; the joists forming the half-space should be built in, as the walls are carried up. It consists of $1\frac{1}{4}$-in. treads and 1-in. risers

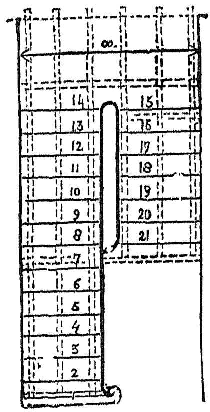


Fig. 1.

mitred to a 1-in. beaded open string-board, and housed and wedged into 1-in. wallstring, 1-in. bar balusters, $3 \times 2\frac{1}{2}$-in. moulded handrail, with proper scroll, curtail step, and turned iron newel.

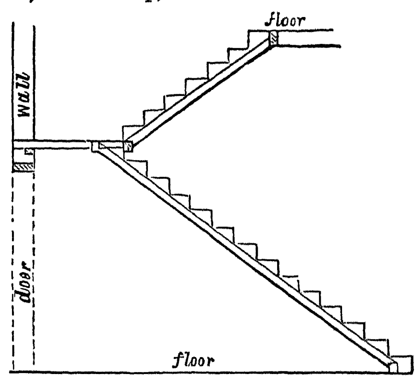


Fig. 2.

"To Prepare the Wreathed String-board."—Make a cylinder or centre to fit the circular part of the well-hole, and mark the springing-lines upon it: these are the position of the risers contiguous

to the half-space; bend a thin slip of wood round this, and transfer the distance between the springing-lines to a straight line, as *a b*, fig. 3. Place a flyer (or common step) before and after this, as shown in sketch; produce the lower edge of the string-board, as *c d e f*; make *d e* parallel to *a b*, leaving sufficient width to receive the floor of the landing, and ease off the angles to the centre of the

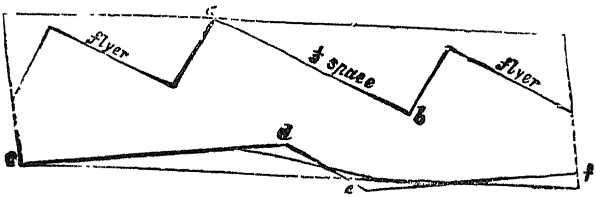


Fig. 3.

well-hole by intersecting lines. A veneer of sufficient size is then moistened with hot water, and being bent round the cylinder to the proper pitch, is blocked vertically with strips of wood about 1 in. or 1½ in. wide, and 1 in. thick, which are, fitted and glued on the veneer; they are then levelled down and backed with strong canvas; the

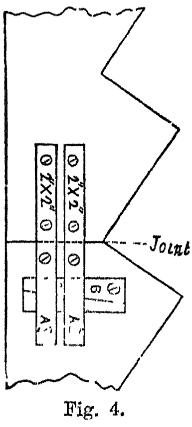


Fig. 4.

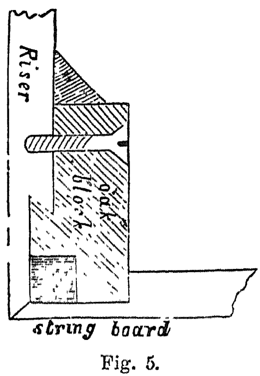


Fig. 5.

springing-lines must be marked upon the string-board before taking it off the cylinder. The steps are then set out as previously directed, the line *a b* being drawn by means of a zinc set-square made to fit the well-hole. The wreathed string-board should always contain a flyer before and after the half-space (or winders, as the case may be), as the joint is then less liable to be seen, and is more easily

cleaned off. The circular part which joins the facia on the landing at the top of the stairs is prepared in a similar way. The wreathed and straight string-boards are connected as fig. 4, by fixing two pieces, A, A, to the latter, grooved across to receive a pair of oak wedges, one of which, as B, is fixed to the wreathed part, and the other being driven in tightens up the joint; it is also usual to put a tongue in the joint. The curtail step is fixed to the string-board in the same manner, the bead on the lower edge of the wreathed parts may be of cane, or lead piping, but we prefer a willow wand steamed and bent round. The iron stay balusters are let in and firmly screwed to an oak block fixed on the riser, as shown at fig. 5; the balusters are knee'd about $\frac{1}{2}$ in. from the face of the riser and string-board, as fig 6, and are concealed by the latter and the returned nosing. Sometimes these are not fixed till the stairs are up; in such cases it is usual to fit a thin piece of wood down upon

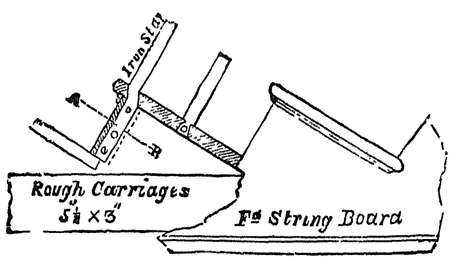


Fig. 6.

the block to cover the baluster, as shown by the dotted line. One of these should be fixed to every fifth riser, or as near this as the step will divide, keeping them rather closer than otherwise, and as near the half-space (or winders) as possible, but not in the ramped part of the rail. The other balusters are dovetailed into the end of the step, as shown; the rest of the diagram represents the string-board as finished.

"To Prepare the Curtail Step."—The block at B, fig. 7, is glued up in three or four thicknesses, crossing the grain of the wood each time. A solid piece, as C, is then fixed to it, and being cut to a pattern of the proper shape, a veneer is cut on the riser, the end of which is made very thin, and being moistened with hot water, is secured in the groove at A by a pair of oak wedges; it is then bent round the block, and tightened with another pair of wedges at D, keeping the riser close to the block with a hand-screw. These wedges must fit very accurately, as the veneer will buckle if one

edge is wedged tighter than the other. The block should be warmed with a red-hot bar of iron previous to gluing the veneer on, to prevent the glue from setting too soon; the hot water softens the veneer, so that it bends more easily, and as it dries fits closer to the block. It is usual to work the hollow moulding under the nosing upon the upper thickness of the block; this is put on after the latter is veneered. "The scroll" is described in figures yet to be given, and on this remarks will be found in the volume "The Building and Machine Draughtsman." Having divided the scroll, and described

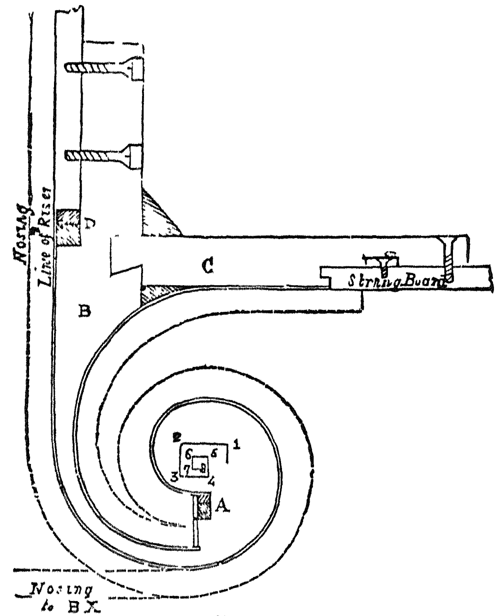


Fig. 7.

the arc B C E, as already directed, join B E, and from C draw a line perpendicular to B E, as C G, from the point of intersection of these two lines draw diagonal lines to the centres A and D; produce these indefinitely; make D E perpendicular to C D, cutting the diagonal line at F, which is the next centre; in this manner all the centres are found, as H, I, etc. To exemplify the scroll, and curtail more fully, we have drawn another arc, as B J, by producing a line from A, cutting the diagonal line in M. Fig. 5 is section through A B, fig. 6.

The example which we are about to give of a staircase is one of

very frequent occurrence. It is a plain return staircase without a landing. Fig. 8 is a plan of the stairs, and fig. 9 is an elevation, the string-boards and walls being supposed to be removed. From fig. 8 set off, on a rod, the distance from A to B, allow for a moulding round the doorway at A, deduct from C to B for the winders, and divide the remainder into the number of flyers required; upon the other side of the rod divide the height into the requisite number of risers, as seen in fig. 9. To prepare stairs of this description, straighten the front edge and the under side of tread where the riser is fixed, leaving the top perfectly rough until the step is glued up and blocked (before which one end of the treads and the riser must be squared). having done this, plane the top of the tread,

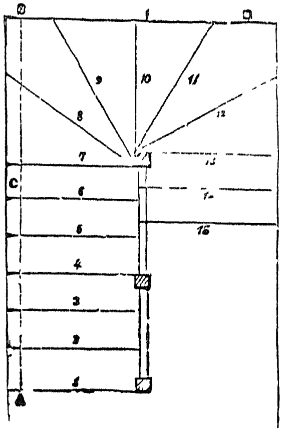


Fig. 8.

from which gauge the riser to the proper height as marked on the rod; gauge a line on the top of a tread as the situation of the next riser; bore holes, to nail or screw it to the said riser from beneath; make the nosing round, and the step is complete; repeat this with all the flyers. Set off the winders, as in fig. 10, those risers which are parallel to the face of the newel being tenoned into it about three-fourths of an inch; bird-mouth each tread to fit round the newel, as drawn on the board full size; mark the line of the upper riser on each, and bore nail-holes as for the flyers; bevel the ends of the risers, and glue and block them up. Set off the string-board as shown in fig. 11 by tacking a straight-edge at the distance *a b* from the top edge, to which apply the longer side of the pitch-board (fig. 12), keeping the tread upwards; mark round this, which shows

the situation of the first step. The shoulder of the tenon should be

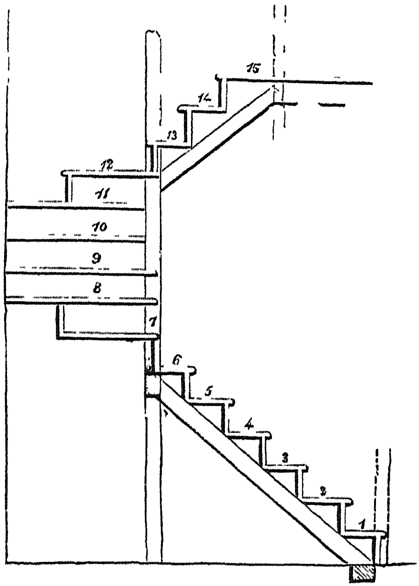


Fig. 9.

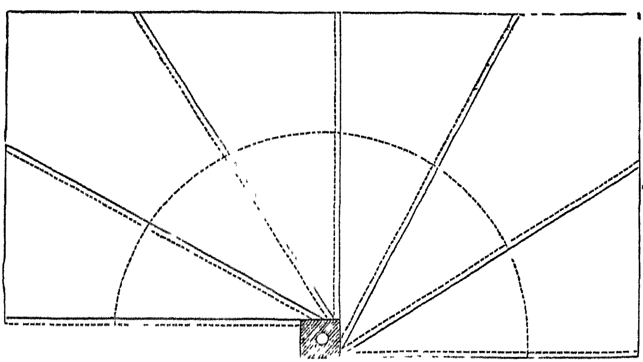


Fig. 10.

at such a distance from the line of the riser as will admit of the

face of the newel finishing level with the first nosing; the tenon must not be in the centre, as only one shoulder is requisite.

Having marked all the steps in the manner described in the last paragraph, remove the straight-edge, and with the template (fig. 13) mark the grooves or housings for the ends of the steps in the string-

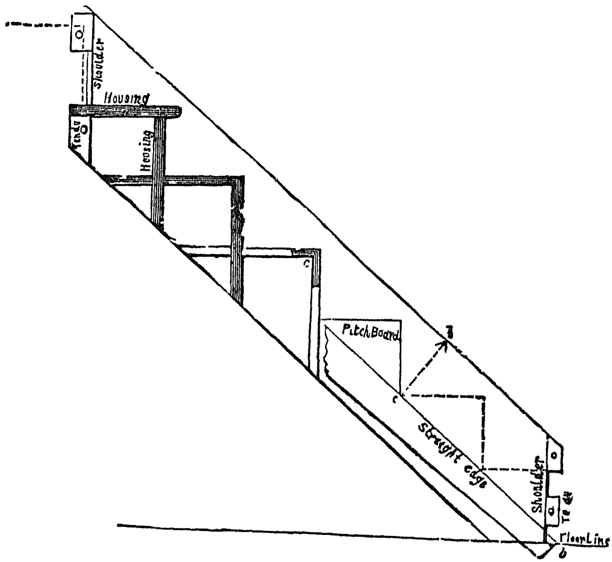


Fig. 11.

board; sink about four inches each way, as c, fig. 8, then cut in the lines with a fine saw the proper depth of the groove, being worked to a line gauged on the lower edge. Having done this, fit the nosing of each of the flyers into its respective groove, keeping the best steps towards the bottom; then lay the string-board flat on the bench,

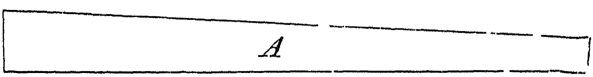


Fig. 13.

place the upper step in its place, and wedge it fast; repeat this with the next step under it, nailing or screwing it to the upper riser from the under side; the steps being all fixed in this manner, glue on the lower newel (the tenons on each end of the string-board having been previously fitted into their respective newels), and fix the first

step; the flight is then ready for fixing. The handrail is of the same length as the string-board, and, like it, must be fitted into the newel and draw-board previous to fixing, and housed in about one-fourth of an inch. To fix these stairs, glue the second newel on the string-board of the first flight, then place them in their proper position, with the newels perpendicular, and wedge a piece of wood between the wall and string-board, to keep the stairs in their proper places; chalk round the under side of the steps on the wall, and scribe the ends up to the brickwork; then take them down, and cut the ends as scribed, and the lines chalked on the wall give the proper length

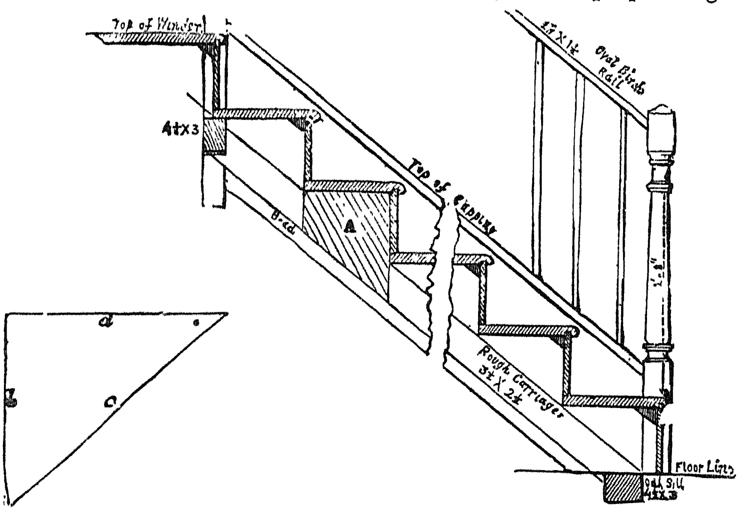


Fig. 12. Fig. 14.

and position of the rough; carriages, which having fixed, lay the stairs in their places, fix the first winder to them by screws from beneath, put a bearer under the middle of it, wedging one end in the wall, and nailing the other to the newel; repeat this with all the winders, then nail brackets similar to A, fig. 14. Block them to the treads and risers, also block the treads of winders to their respective bearers, fix the rail coping and balusters, and the staircase is completed. The same method of setting off string-boards applies to those stairs which have a wall-string.

Fig. 15 exhibits the method of finishing the string-board on the landing in cases where the facia B requires to be fixed farther back

than the riser A, to obtain head-room; and the method of finishing the rail.

In our remarks on staircases, for purposes of convenience of arrangement, we include here descriptions and illustrations of stone staircases. For these we are indebted, as well as also for a few which follow made of timber, to a Continental source.

There are two principal varieties of staircases in use: one as in fig 1, *ante*, in which the steps are parallel to one another, and are of some width of "tread"—that is, the part on which the feet rest

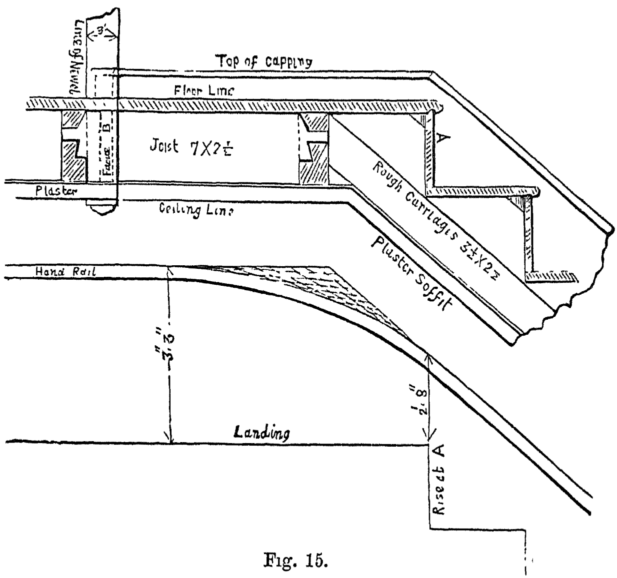


Fig. 15.

in ascending and descending; the other in which some of the steps have their treads of unequal width—that is, triangular in shape, as in fig. 8, *ante*, at 7, 8, 9, 10, 11, and 12. Those steps so shaped are called "winders." In large stone staircases these triangular-shaped steps are generally avoided, on account of their want of elegance; and they are constructed with straight flights and "landings" between two walls or well-holes. In the first case the steps are made fast at their ends to the straight walls, and the under part may be seen; but when they are too large to be made of one piece—that is to say, when they exceed 1 metre 50 centimetres—they rest on solid masses.

In this second case the steps rest upon inclined pieces, re-entering in the angles, or rather on parts of arches. These staircases have an

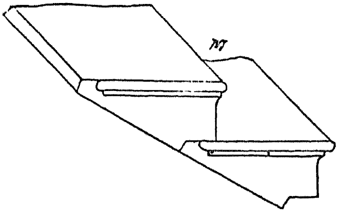


Fig. 16.

appearance of grandeur and solidity suitable for buildings whose ground floors are raised Stone staircases may be made with or

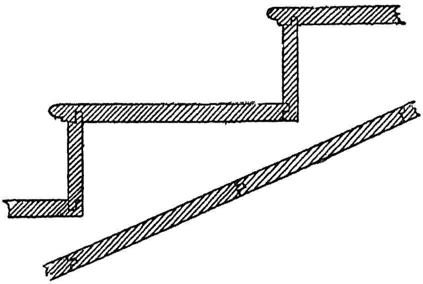


Fig. 17.

without carriages and newel posts. The steps should be supported by their joints alone, and form below an inclined and flat surface

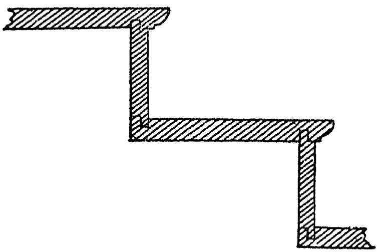


Fig. 18.

terminated by a groove or elbow, in such a way that each groove made on the front of a step fits in exactly to a section formed on

the back of the other, as is represented by the sketch in fig. 16; the steps being made fast on one side to the partition wall, and maintained there by a good bearing surface, which may quite well be supported without carriage and newel posts. In this case the steps are profiled as indicated in fig. 16. When carriages are added they increase the solidity of the staircase by supporting the steps at their end in such a way that they cannot move from their place. Partition walls are those which inclose the staircase, and to which are made fast the ends of the steps. The space comprised between them is called a "well-hole," daylight passing down the space between the carriages. The width of the upper part of the step, the part upon which the foot is placed, is called the "tread," the vertical part the riser, and the whole of the step comprised between carriages is called the step. The steps cannot be made higher than 16 cm. by 34 cm. of tread. When the height is increased it is necessary to diminish in the same proportion the tread. These two dimensions added together should give as nearly as possible 50 cm. In staircases where the steps are only from 12 to 15 cm. wide the tread increases in proportion as the height diminishes. The most convenient height for the riser—the one generally given—is about 16 cm.; it is sufficient to ascend and descend easily. The study of a staircase presents several difficulties; the principal consists in the distribution of the steps in section with regard to the point of starting and of arrival, especially for private staircases, the space allowed for which is often very limited. But whatever the plan of the staircase, the division must always be made upon a line passing through the middle of the stair. If there are triangular sloped steps, the division is made on an arc of circle corresponding with the line on the middle of the straight parts. The division of the steps being made in perspective, it now remains to make them in raised plan. This operation is not without difficulty, on account of the rigorous accuracy which it demands; for the smallest error of calculation repeated at each step would produce in the height of a story a great difference. We cannot, then, recommend too great accuracy in the execution of this work. The draughtsman, therefore, should always make his drawing the size of execution (full size), with the section on which he draws the projections, which enables him to set up squares, which he gives to the stone-cutter or carpenter, according to the nature of the staircase. If the staircase is a stone one, he places the steps level on the length without any prop, taking care to give them a slope of about a millimetre in the direction of the tread. An uninterrupted suite of steps comprised between the point of starting and the upper landing is termed a flight of stairs. Staircases are com-

posed of one or several stairs, and each stair may have several flights. When it is composed of several flights it is necessary to diminish in ascending the number of steps from one flight to the other, in order to have more landings.

Timber or wooden staircases are, like stone ones, formed of steps supported by carriages, and by newels. Steps may be solid or not; when they are solid (which is rarely met with) they are composed of

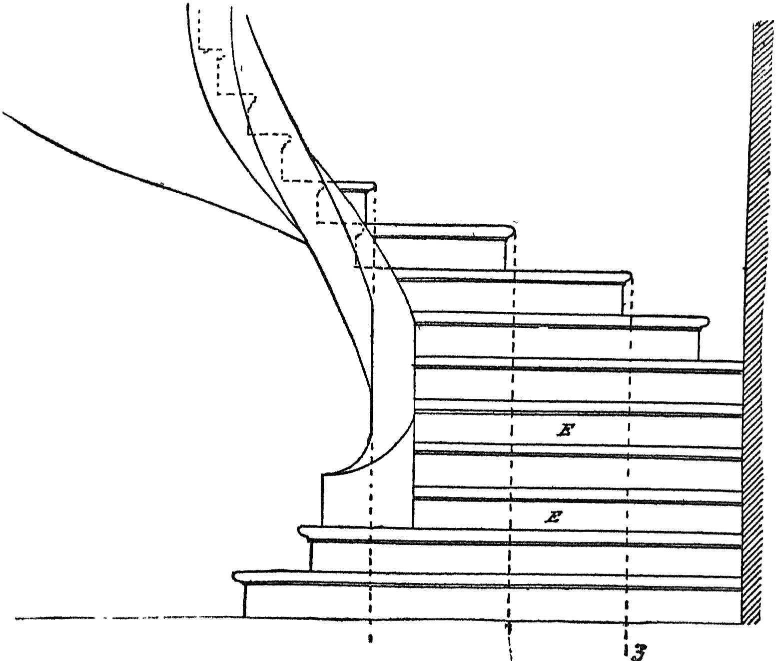


Fig. 19.

a single piece of wood, cut as for stone steps, as already mentioned. In the other case they are composed of two boards, one vertical, the other horizontal, and are joined with grooves and tongues. In fig. 17 the steps are on one side made fast to the wall, and on the other mortised into a piece of inclined wood called a carriage or quarter, or rather into a solid mass, either of wood or stone. The carriages are composed of a piece of wood properly secured, to which is given a height of from 32 to 36 cm. by 9 cm. of thickness; they are always

placed parallel with the partition wall. They may be visible or in frames. The carriages are formed of several pieces, joined by tenon and mortise or scarf joint, and fastened with iron pins. In visible carriages the steps fit into the partition or inner surface; the under part remains visible (fig. 18).

Straight carriages present no difficulty in their execution; it is sufficient to draw upon their interior surface the outline of the steps in order to hollow in them the grooves which are to receive them. It is not so with curved carriages, the design of which demands a certain amount of work. These carriages should be considered as parts of hollow cylinders cut obliquely, whose base is indicated by the projection in plan. Fig. 1, Plate I., indicates the drawing of lengthened curves of a carriage whose projection in plan is circle. To find the width and the slope of the flight in which should be taken this carriage, we must commence by making the plan on which is indicated the width of the steps and of the carriage, fig. 2, Plate I., and a section indicating the height of the steps, fig. 17; then by raising perpendiculars from the points 1, 2, 3, 4, etc., and leading horizontals on each height of step, fig. 7 (see also section to the left in the annexed engraving, fig. 3, Plate I.); then intersection will give the outline of the steps close to the carriage. Pass through these points of intersection a curved line P Q; this line will represent the slope of the carriage. By leading parallels M N, R S, to P Q, we have the angles of the upper and under part of the interior carriage. In passing through their intersection curved lines, we have the outside angles of the carriage.

To find the curve or template, fig. 3, Plate I., raise perpendiculars to the line K L parallel to the slope of the carriage of all the points of meeting of the vertical lines 1, 2, 3, 4, etc., raised from the plan, and carry on these lines the size of the corresponding ordinates drawn on the plan. By passing through these given points lengthened curves, these curves will form the internal and external angles of the template. With this template we draw the pieces of wood which should serve to form the carriage by taking away all the wood outside the drawing. The curved surfaces being thus made, we indicate on the internal one the outline of the steps to make the grooves which should receive them.

We now come to the class of staircases having winders and curved steps. We call triangular sloped steps, or circular steps, those which are fastened to triangular carriages. In old staircases these steps all tended to the same centre—that of the triangular block. This construction is faulty, and often became dangerous because there was little or no tread left at the inner end or neck. To remedy

as much as possible this inconvenience, staircases have been contrived with hollowed newels, open, and with circular blocks or continued carriages, such as represented in figs. 19 *ante,* Plate XX., and in fig. 1, Plate II. In these staircases the parallel steps nearest to the circular blocks vary in width in favour of the circular steps, following a progression which increases or diminishes according as we withdraw from or approach the straight carriages. This arrangement of the steps is called balancing ; the object of it is to give a nearly equal width to all the steps, to avoid the projection or bend which is formed at the meeting of the lines which pass through the angles of these steps when they suddenly change in width. To obtain the balancing of the steps, it is sufficient to trace upon a plan the two

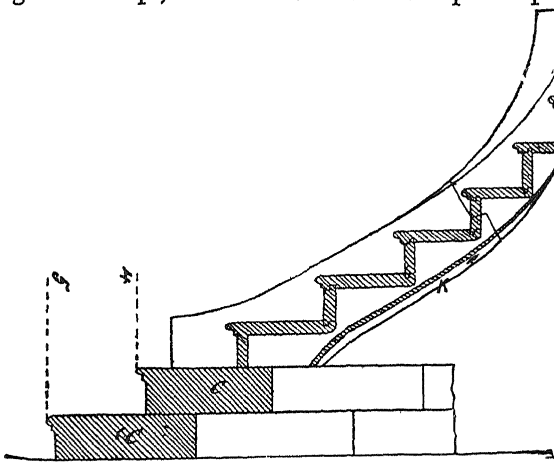


FIG. 20.

carriages, straight and curved, A B, B C, fig. 2, Plate III., which correspond to the small and to the large widths of steps ; the height being the same for all, there result two lines of different inclined planes which will form an angle B at their junction. Upon these lines A B, B C, if we raise indefinite perpendicular lines, E D, F D, we shall have at their junction D the point of centre of the arc of circle which should form the junction of the two lines of inclined planes. Prolonging, then, the lines of height of steps to the meeting of the curve, their intersection will give the points *a*, *b*, *c*, *d*, *e*, *f*, which will indicate the progressive width of the joint of the steps against the straight and curved carriages; by carrying back all these divisions in the same order on the plan, and making straight lines pass through

these points and those already indicated in the middle line, L M N, parallel to the carriages, we shall have the direction of the steps.

Timber staircases are generally comparatively small; they serve as private staircases between apartments situated one above the other. The smaller the space they occupy the more attention do they require in their arrangement. As the points of starting and

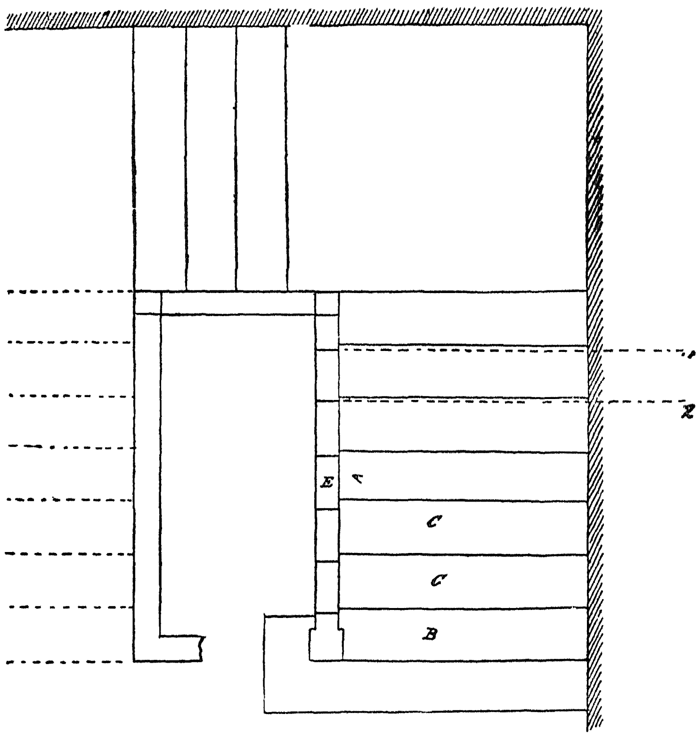


Fig. 21.

of arrival are fixed, we are often obliged to twist them round in order to make more room to ascend and descend freely without fear of knocking the head against the lower part of the upper steps. The construction of a staircase becomes then one of the most difficult parts of the joiner's art, to arrange the flights with elegance and ease; the pieces should be cut beforehand so as to fit into one

another and contribute to the general solidity. Steps may be in one piece, or of several pieces joined together. When they are solid, their section and corresponding groove are made like those in stone or wood; they are firmly joined together at their ends by double bolts with screws and nuts, which bind them successively together to the steps of the lower and upper part by crossing them obliquely on the width. Often, to avoid the cracks to which solid wood is liable, we cover the wood with light joiner-work, which hides the

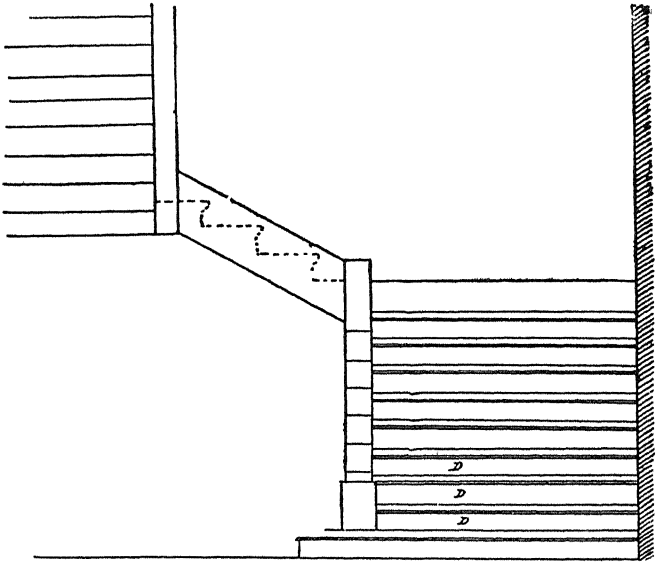


Fig. 22.

defects of the wood, and gives a smooth surface, which adds to the beauty. When the steps are joined they are composed of two boards: the upper one, whose front end is ornamented, may be 4 cm. thick; it is joined in mortises made in the carriages, and sometimes with tenons; the other board forming the front is joined to the upper part with groove and tongue. We give them about 3 cm. in thickness (see figs. 17 and 18, *ante*). If we wish to form a ceiling or under surface, the planks which compose it will be joined together and to the carriages with grooves and tongues, or dovetailed. This

latter method is preferable because, the wood being liable to shrink, it hides the joints which open in a disagreeable manner. When the staircase is composed of a newel, the steps turn spirally round the newel, and are joined with tenon and mortise.

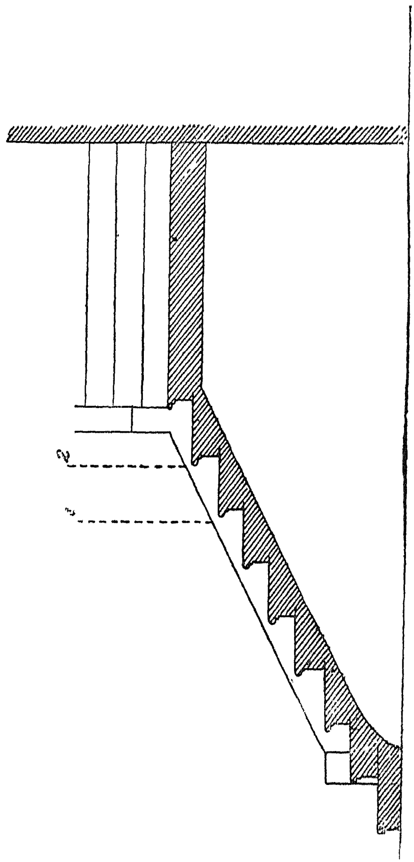


Fig. 23.

Staircases with flyers or parallel-sided steps and well-hole are illustrated in figs. 21 22, 23, and 24.

In staircases of this kind, two principal things are to be considered: the steps, and the carriage. Sometimes the steps fit on one side into

the wall of the staircase frame, on the other into a carriage constructed on the side; sometimes they are supported one upon the other by their fastening on one side, and by their section forming a head or carriage on the other end; sometimes they are supported without carriage solely by their grooved section, the fastening of one of their ends, and the abutment against the upper and under landings.

In the example here given, the carriage is formed by the head of the steps.

Two methods of joining steps and carriage are proposed: the one as in fig. 25, the other as in fig. 24. Both, as may be seen, satisfy the data of the programme.

Fig. 16, *ante*, is an example of steps without carriage, the solidity of which is assured by the grooving of one of the steps upon the other, and the perpendicular section on the lower surface of each.

It is to be observed that in staircases without carriage the compass of section must be large in proportion to the strength of the stone. For strong lias stone, this section is the third of the height of the step, and the groove the double.

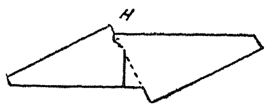


Fig 24.

The loss of stone which the system of steps bearing carriage entails may be rendered much less by taking two steps out of the same block; then the broad part of the one is taken out of the narrow part of the other.

We now come to notice the class of staircases with circular well-hole and flyer and winders, sometimes known as hanging staircases. This, though generally constructed of wood, may be made of stone, the more so as the method of construction suitable for it is that used for stone staircases. Its steps are solid, of one piece, and finished with a moulding; each one returns horizontally by about 2° (0·054′) the preceding one, and is supported by a joint which is perpendicular to the surface of the under part of the steps. The carriage fits in to the first step, which is of wood and securely fastened to the foundation wall. The under part of the steps is visible.

In a newelled staircase with continuous carriage the larger and more hollowed is a staircase with carriage in circular well-hole, the narrower are the steps at their end, and consequently the less neces-

sary are the circular steps to secure a firm footing; nevertheless they cannot be done without when we wish the arrises of the carriage and of the steps to be directed in their whole extent without projections, bends, or angles. To effect the balancing of the steps we may examine fig. 29, and figs. 1 and 2, Plate III. Formerly steps were made of ends and rafters laid flat above and profiled in front; one of the ends was made fast to the wall, and the other to the carriage. Laths below the steps covered with plaster formed the under part or ceiling of the staircase, and a plastered and paved joint was effected above the steps. Nowadays the steps are made of one piece; they are placed one above the other, like the stone ones, and the ceiling is besides rough cast on closed table-work, to join the steps with more solidity. To keep the coating on its contour, and to prevent the shrinking which takes place when the wood has dried, we make in the inside of the carriages the groove *k*, indicated on fig. 2, Plate III.

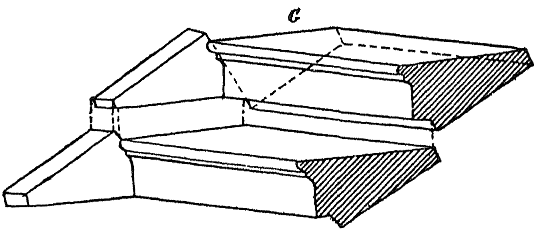


Fig. 25.

As in freestone staircases, the carriage is made out of a single piece as far as possible—that is to say, as far as the thickness of the wood allows us to find the necessary curve without taking away more wood than we leave; otherwise this carriage is made of several pieces joined in section, or in scarf joint with keys.

Joiners occasionally make private staircases leading from one story to another in the interior of an apartment. Although of light wood, these staircases are nearly always constructed upon the same data as those of stone and wood: the processes of drawing, of section, of joints, and the means of raising the elevations on the plans, of developing the curves of the carriages in circular well-holes are the same.

The Handrails of Staircases.

To understand the principle upon which handrails are executed, the young reader should study the diagram in fig. 26—for the more complete comprehension of which we would recommend him to look

at the cognate projections in the volume entitled "The Building and Machine Draughtsman." Divide the outer semicircle *a b c* into any number of equal parts, as 1, 2, 3, 4, etc., radiating to the inner semicircle; draw lines from these perpendicular to the base line, *a b*, and centre *c*, cutting the raking line *d e* in the points 1′, 2′, 3′, 4′, etc.; then, distance 1 *f* being set off from 1′ to *f*′, 2 *g* from 2′ to *g*′, and so on, the semi-ellipsis *e f′ g′ h i j k* is the true section of the semicircle *a* 1 2 *b*. This contains the entire principle of handrailing: supposing the lower diagram to be the plan of a rail, and *c d* the

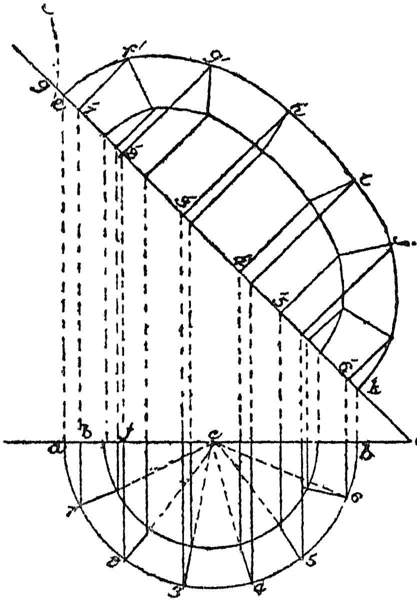


Fig. 26.

pitch, the semi-ellipsis of upper diagram would be the face-mould. If a wreathed piece of rail is laid upon a level surface it will rest on several places, more or less, and the distance from these resting-places to the highest part of the rail is the exact thickness of the plank required.

"To Obtain the Falling Mould."—Make a pattern of thin deal to the plan of the rail, and mark and figure the risers upon it, as in fig. 26; apply the round edge of this upon a straight line, and, turning it along, mark each ordinate from it, as 1, 2, 3, 4, etc. (A B,

fig. 27); allow about three inches past the springing to join the

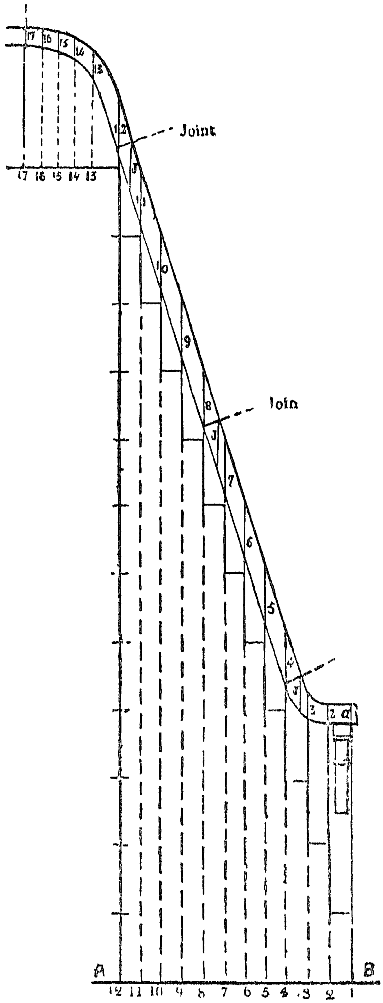


Fig. 27.

straight rail on the landing, and divide it in the same manner, which

gives the exact development of the handrail (the workman in setting out this supposing himself to be on that side of the rail next the wall, otherwise the perpendicular lines will be on the wrong side of the falling mould). From the points 1, 2, 3, 4, etc., make 1 *a* equal to the height of a step, and 12 *b* equal to twelve steps; join *a b*, and the intersection of the raking line with the perpendiculars gives the height of the various steps; at any equal distance from this draw two parallel lines to represent the thickness of the handrail, as *c c*, which, as the stairs are steep, will be three feet high to the upper side, measuring plumb over the face of the riser; make the rail on the landing five inches higher, and curve the angle, as shown by intersecting lines; keep the newel sufficiently high to allow the level mitre-cap to be eased neatly into the raking-rail; mark and figure

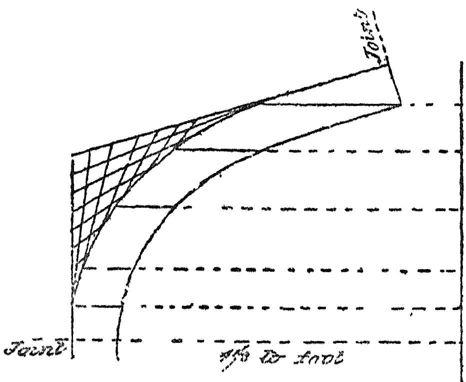


Fig. 28.

the situation of each riser, also the joints; and this completes the falling mould. No length of wreath-rail should exceed a quarter of a circle, as beyond this it runs into a curve of contrary flexure, thereby requiring extra thickness of stuff.

"To find the Pitch and Thickness of Stuff required for the Rail; thence to trace the Face Mould."—Mark and figure the various heights of the upper and under edges of the falling mould upon the blade of a deal T-square, which is made to move tightly through a mortise in the stock, and applied at a straight-edge, as A B, fig. 28, which represents the upper part of the falling mould upon a larger scale; the square, with the heights marked on it, is shown at A, fig. 29. Fasten the pattern, fig. 30, with a broad-headed nail, as at B, fig. 33; apply the T-square to a straight-edge, as *a b*, and prick

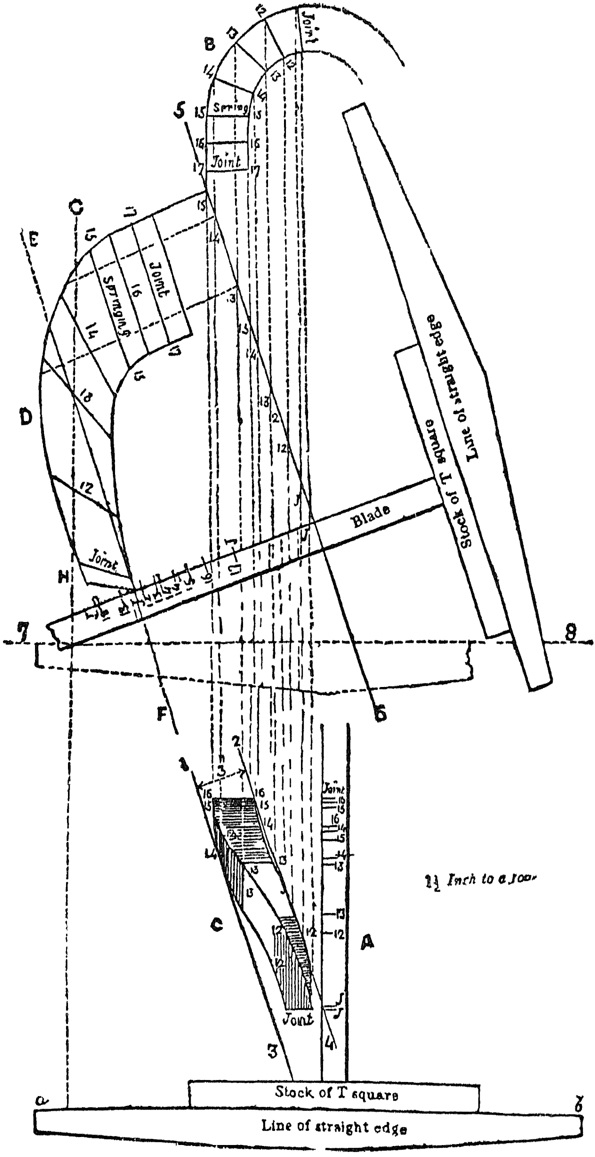

Joint
Spring
Springing
Joint
Blade
Stock of T square
Line of straight edge
1½ Inch to a foot
Stock of T square
Line of straight edge

Fig. 29.

off each height of the falling mould, as marked on the blade, perpendicular under the corresponding points on the outer and inner edges of plan at B, as 16 16, 15 15, and at C, where the twist of the rail is shown by tracing a line through the various points. The dotted lines from B to C are drawn in the proper position, but it must be turned round on the nail as a centre till the heights are

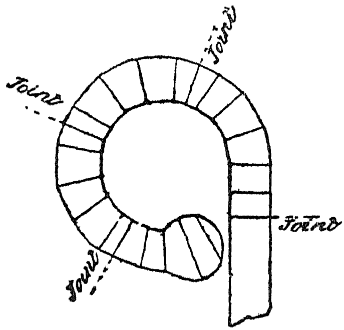


Fig. 30.

contained in the least distance between two parallel lines, to define this more clearly; but in practice a slight pencil-mark at each height is sufficient. There is no correct rule to fix the pattern B at once in which to represent the thickness of the plank required to square up the rail, as 1 2 3 4, at C; but as the corners are worked off in moulding, it may be cut out of thinner stuff still, as fig. 38, where

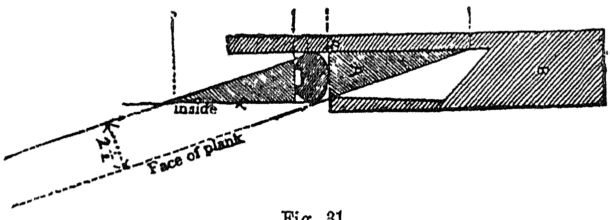


Fig. 31.

A is a view of the upper end of the rail-piece, a section through A B, fig. 33, showing the position of the rail as finished, and the superfluous wood required to be cut away in squaring it up. By this method the rail may be cut out of any given thickness of stuff, by moving the pattern till the distance between two parallel lines is equal to the required thickness: the length of the face-mould depends

upon the pitch, which is regulated by the thickness of the plank. Draw a line, 5 6 (fig 29), parallel to 1 2, 3 4, at C; apply the T-square to a straight-edge at the dotted line 7 8; set 15, 14, 13, etc., on the line 5 6, perpendicularly under the corresponding ordinates, at B, at the same time marking the various heights of the outer and inner circumference upon the blade of the square transfer these heights as the figures direct to 5 6, and a curve being traced through them

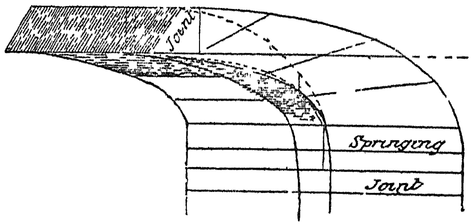


Fig. 32.

produces the face mould as D; radiate the ordinate across this, as shown, draw the pitch-line, E F, at any equal distance from 5 6, and intersect it by another line, as G H, perpendicular to 7 8; then the angle formed upon the face mould by the junction of these lines is the pitch of the rail. It will be seen by this that the face-mould is pricked off the pattern B, in the same manner as the semi-ellipsis

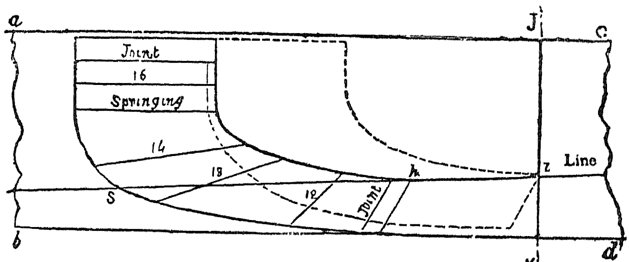


Fig. 33.

in fig. 30, but by transferring the heights upon the T-square instead of drawing lines upon the board, which is more confused and troublesome, the face-mould must be made about $\frac{3}{4}$ in. longer, to allow for the joint.

"To Apply the Face-Mould to the Plank."—Let *a b c d*, fig. 33, represent the plank; mark the face-mould upon it, as shown; continue the pitch-line *g h* along the plank, and make *h i* equal to *h i*,

fig. 34. Draw J K perpendicular to *g h*, intersecting it in the point *i*; produce *j k* and *g h* on the other side of the plank by pushing the notch-stick, fig. 39, upon the plank at the line *j k*, till the mark *a* on the longest leg is at the point *i*; then the other leg being immediately under this shows, the proper position of *i* on the other side of the plank; from this draw a line coinciding every way with the plane passing through the pitch-line *g h* at right angles to the face of the plank; keep the extremity of the face-mould at *h* fair with the point *i* on the plank; making the pitch-line on the former range

Fig. 34.

with that on the plank, as shown by the dotted lines; cut the rail-piece out as marked making the teeth of the saw range with the ordinates figured on each side of the plank, as 16, 15, 14, etc.

"To Square up the Rail."—Draw perpendicular line upon the rail-piece from the various ordinates, as shown at fig. 32, which represents the rail-piece previous to being squared up, and applying the falling mould, the lines drawn upon which will agree with those on the former, slip the notch-stick upon the rail-piece at each line, keeping the mark *a* at the upper edge of the falling mould, and mark the position of the short leg upon the corresponding ordinate

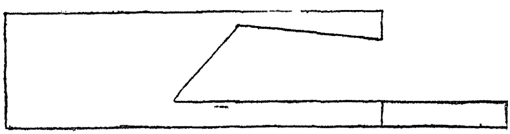


Fig 35.

of the inner circumference of the rail, which is squared by sawing the superfluous wood away to these marks, making the teeth of the saw radiate to the various lines as figured, having worked the upper side of the rail to this gauge and to the proper thickness, and saw it as before; the dotted lines show the position of the rail when squared up. This system of handrailing has no reference whatever to the edge of the plank, either bevelled or otherwise. The ends of the face-mould are left rough, and about three-fourths of an inch long, to allow for cutting the joint; the proper pitch of the rail in

the plank is produced upon the pitch-line; and when it is cut out, as fig. 32, and placed in proper position, the ordinates on the outer and inner circumference will be perpendicular over the corresponding points in the plan of the rail.

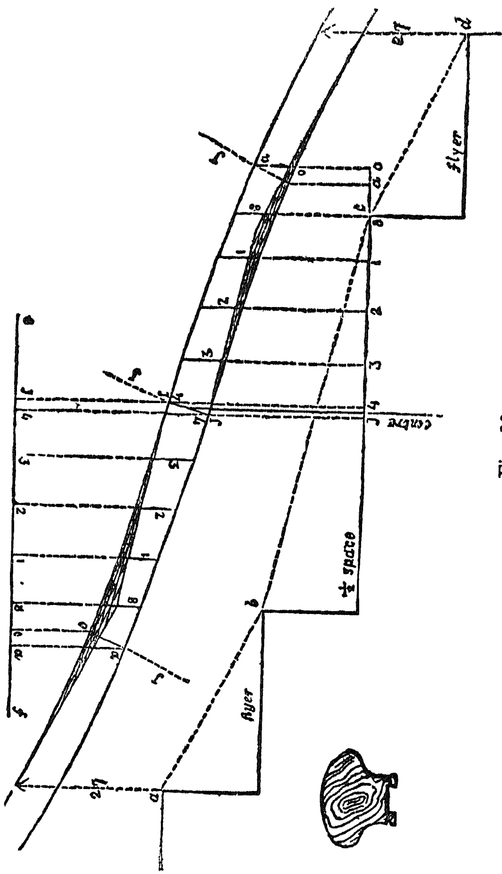


Fig. 36.

"To describe the Falling Mould of a Handrail," fig. 36.—The falling mould is described by placing a flyer before and after the half-space, and drawing lines to join the risers, as *a b*, *c d*; at any equal distance from these set off two parallel lines to represent the

thickness of the rail, and ease off the angles by intersecting lines, as shown. In the lower wreath piece, the under side of the rail is produced first, and the upper side drawn parallel to it, while in the upper wreath piece the upper side is drawn first, as shown; by this

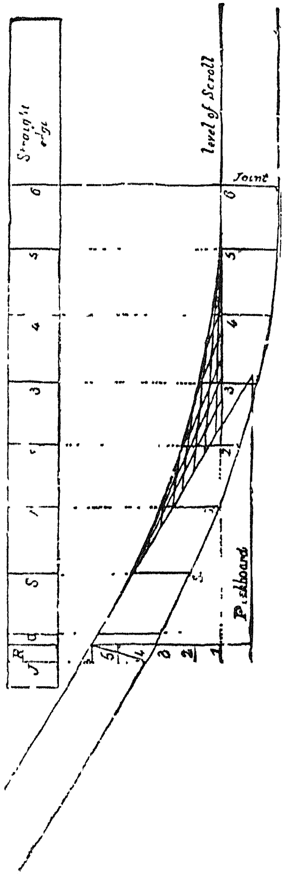


Fig. 37.

means the same falling mould is applicable to both. By turning it upside down this is evident, as the distance from the upper side of the rail to a given line $e f$, drawn parallel to the development of the half-space, corresponds in every way with the distance from the

latter to the under side of the lower wreath piece; therefore only one falling mould and one face mould is required. The falling mould for the wreath piece over the landing at the top of the stairs, fig. 37, is produced as previously described. A, fig. 38, is a pattern of thin deal to the plan of the rail over one-quarter of the half-space; B represents a rail in that position, requiring the thinnest stuff; the distances of the various ordinates in the plan of the rail from the line *a b* at A are pricked off perpendicular to the raking line *c d*, and a curve being traced through them produces the face-mould at C; this is done in practice by means of a T-square. Fig. 39 shows rail

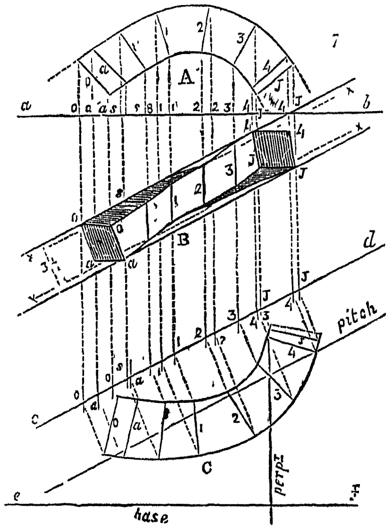


Fig. 38.

for landing at the top of stairs; face-mould, etc., for this are obtained similar to fig. 38. The dotted lines *x x*, *x x*, in figs. 38 and 39, show the real thickness of plank required; the outer lines contain the rail as squared up previous to being moulded. To describe the falling mould, fig. 40, divide the height of the pitchboard, *a b c*, into six equal parts, and make the top of the scroll level with the first part; then divide the hypothenuse (which represents the upper side of the raking part of the rails, and the level of the scroll into any equal number of parts, from which describe a curve, as shown, and draw a parallel line for the under side of the rail. The development is

obtained by dividing a deal pattern of the plan of the scroll into any number of parts radiating towards their respective centres, as A, fig. 41, and applying the round edge to the level of the scroll,

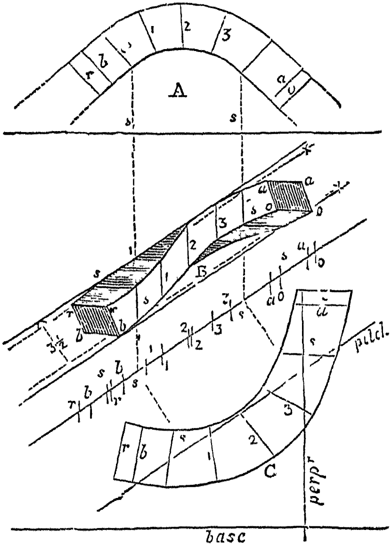


Fig. 39.

fig. 40; turn it along, and transfer each ordinate upon it to the falling mould, as J O S, 1, 2, 3, etc., then fix a thin slip of wood, as X X, parallel to the level of the scroll, to which apply the T-square, and mark the heights of the upper and under edges of the falling

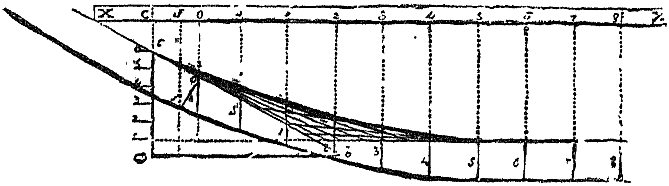


Fig. 40.

mould upon the blade; he ordinate *c* in the plan of the scroll at A, fig. 41, is the position of the line *a c*, fig. 40, and must be kept fair at C, in developing the scroll upon X X. The pattern A is then laid

down, and the T-square applied to a thin straight-edge, Y Y, fixed at any convenient distance from A, which is turned round under the square, till the various heights on the lower end of the blade of the

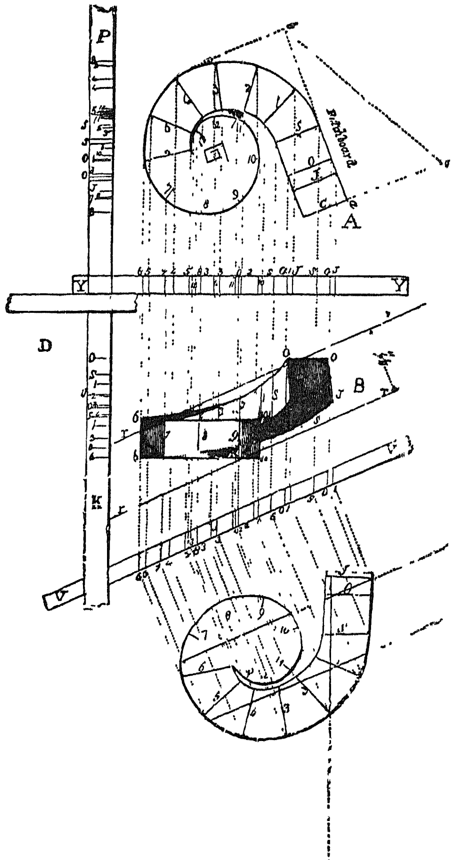


Fig. 41.

latter are contained in the least distance between two parallel lines, representing the thickness of stuff required, as *r r*, *r r*. Another thin straight-edge is fixed parallel to these, as V V. The height of

obtained by dividing a deal pattern of the plan of the scroll into any number of parts radiating towards their respective centres, as A, fig. 41, and applying the round edge to the level of the scroll,

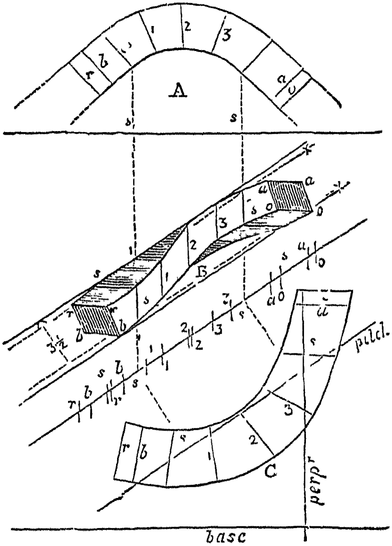


Fig. 39.

fig. 40; turn it along, and transfer each ordinate upon it to the falling mould, as J O S, 1, 2, 3, etc., then fix a thin slip of wood, as X X, parallel to the level of the scroll, to which apply the T-square, and mark the heights of the upper and under edges of the falling

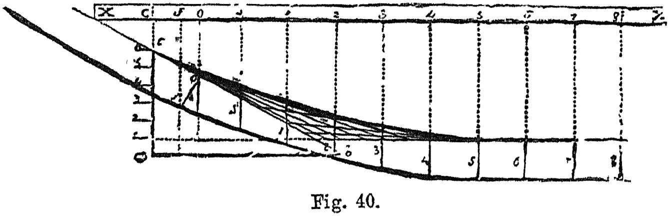


Fig. 40.

mould upon the blade; he ordinate *c* in the plan of the scroll at A, fig. 41, is the position of the line *a c*, fig. 40, and must be kept fair at C, in developing the scroll upon X X. The pattern A is then laid

each ordinate in the plan at A is then marked on the upper end of the square, at the same time marking its position upon V V, with the lower end as the figures direct; the square is then turned over, and being applied to the ordinates upon V V, the heights of each are pricked from the blade, and a curve being traced through these produces the face-mould, as C. Two pitch lines are necessary on this, it is so much wider than the face-mould of a common wreath

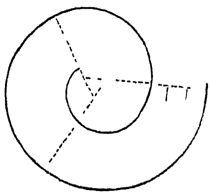


Fig. 45.

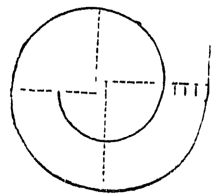


Fig. 46.

rail. The dotted lines are not required in practice, neither is it requisite to draw the twist of the scroll, in ascertaining the thickness of stuff; the ordinates 0, 6, 10, at B, are sufficient, as these are the most prominent parts of the scroll. The face-mould is then applied to the plank, and the railpiece squared up. A, fig. 48, is a deal pattern of the scroll to join the straight part of the rail; B, thickness of stuff required; C, face-mould traced for the same. By making

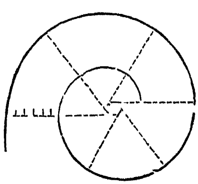


Fig. 47.

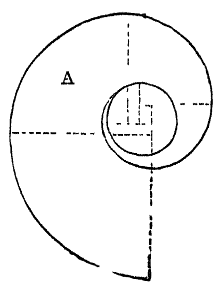


Fig. 48.

a joint at the junction of the level and twisted parts of the scroll, the falling mould can be cut out of a 3-in. plank; the other wreath parts of the rail are respectively 3 in. and 2½ in., but by tracing each face-mould from a 3-in. plank the railpieces might be cut out of each other, thereby causing less waste of stuff, and the straight rail could also be cut edgeways out of the same plank. Fig. 42, a section through the level part of the scroll and curtain step, shows

the mode of fixing the iron newel: a nut or collar is screwed to the scroll, after being turned and fitted to the upper end of the newel, which is fixed to the step by means of a screw-pin forged upon the lower end, as shown. Fig. 43 is a gauge, consisting of a beam B in which two arms are dovetailed about $\frac{3}{8}$ in. asunder, and touching each other at A, where they are secured by a screw; by placing a pencil between these, at the required distance from B, and moving the beam perpendicularly round the outside of the railpiece, a line is traced on the face of the latter. Fig. 44 is a collar of hard wood about 5 in. long, to guide the bit in the proper direction and depth when boring for the hand-rail screws; it is held firmly on the end of the rail, and answers the same purpose as a dowel-box in sash-

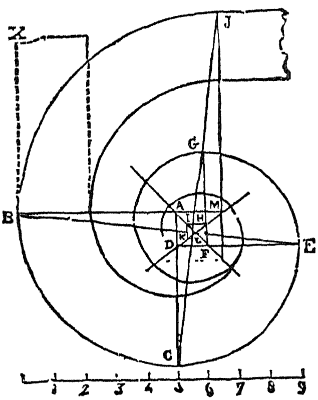


Fig. 49.

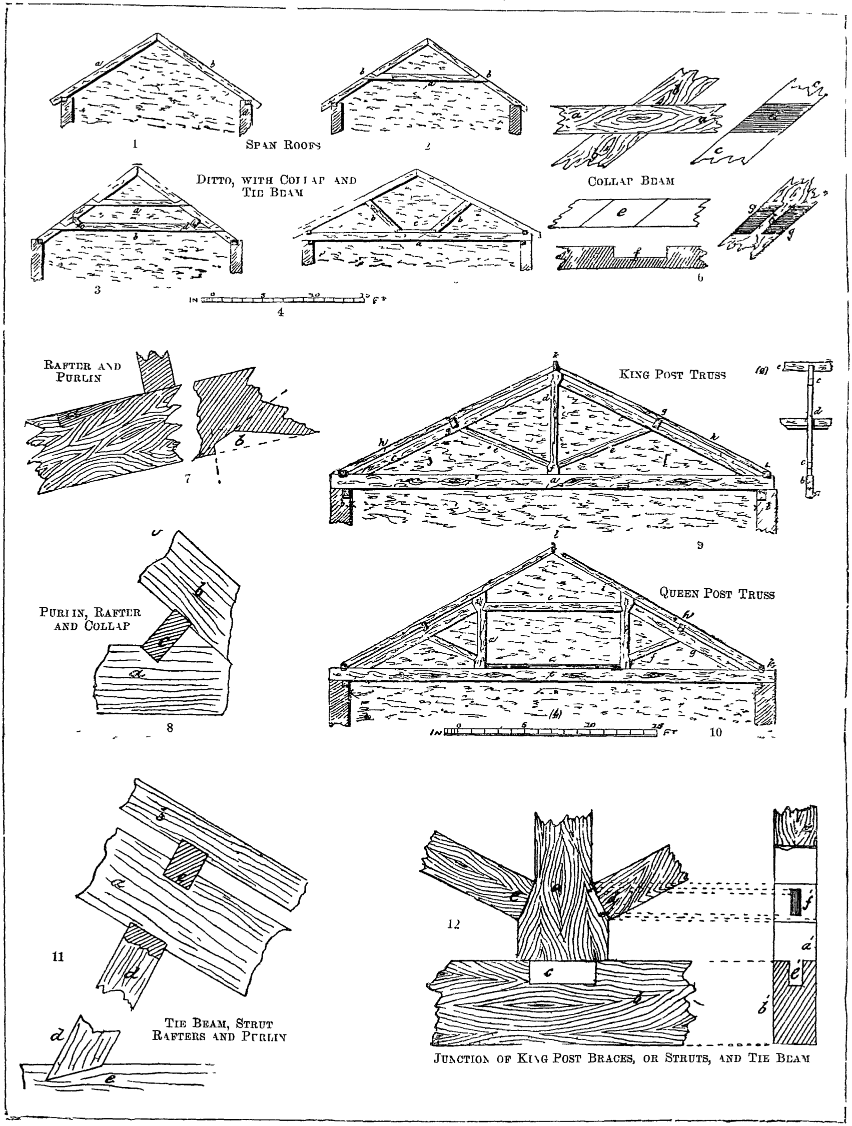
making; it is usual to put a dowel in the joint on each side of the screw.

In the volume entitled "The Building and Machine Draughtsman," the young reader will find various problems connected with scrolls and spirals, to which we refer him. In figs. 45, 46, 47, 48, and 49, we illustrate certain spirals. The logarithmic spiral cannot be described by means of circular arcs, and the same may be said of the architectural spiral; but we have given some methods of describing spirals by circular arc that will give results near enough for practical purposes. The centres of the adjoining arcs must always be on the same radial line, else there will be a protuberance on the curve, and the greater the number of arcs taken the more nearly will the spiral

approach to regularity. Let the proposed distance between the revolutions be divided *into as many equal parts as there are to be arcs in one revolution*; and at the centre construct a regular polygon, with sides equal to one division, and with as many sides as there are divisions; the angles of the polygon will be the centres for describing the spiral, as shown by the accompanying figures. If a spiral be drawn to begin from a circle at the centre, let the arcs be described from the angles of a rectangular fret, as in fig. 49, the sides of which may increase in any regular proportion, by which method a pleasing curve will be obtained.

THE END.

THE CARPENTER



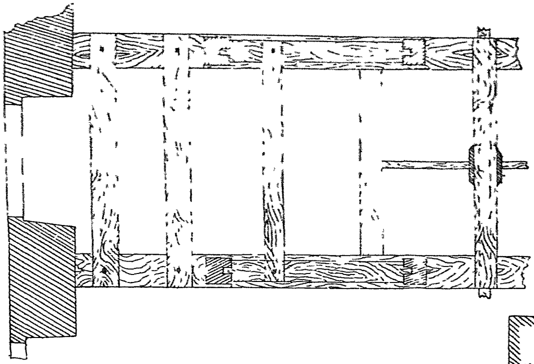


Fig 1

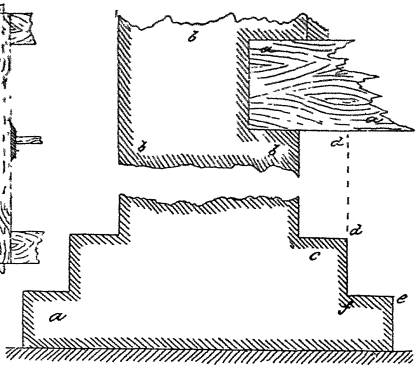


Fig 2

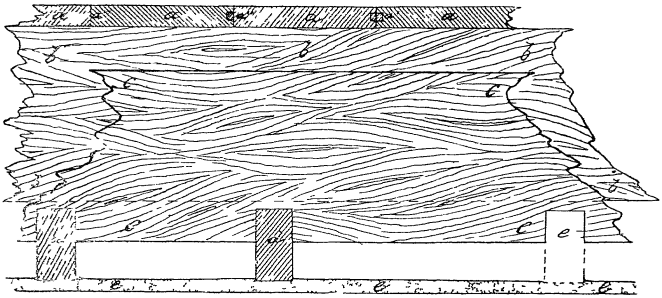


Fig 3

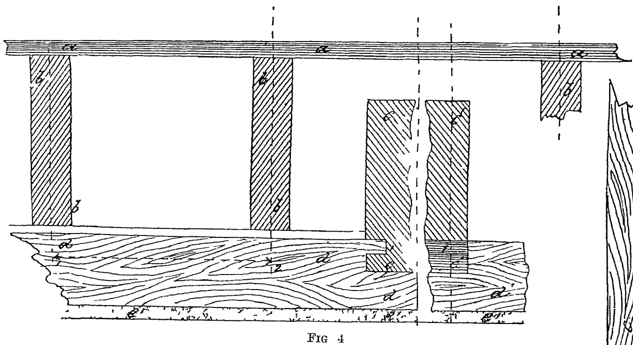


Fig 4

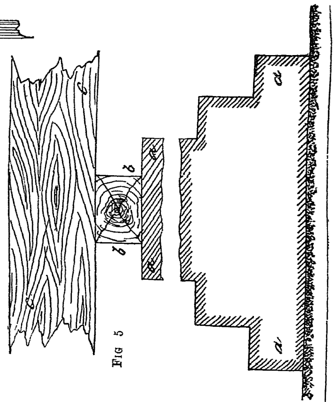
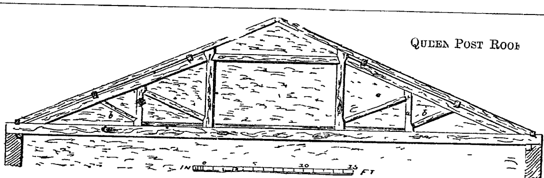


Fig 5



Queen Post Roof

Fig 1

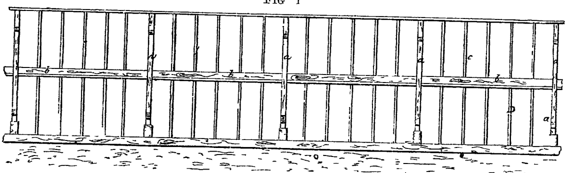
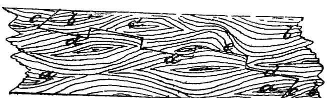


Fig 2—Side Elevation of King-Post Roof in Fig 9, Plate I



A

Scarf Joint

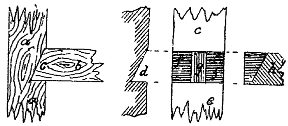
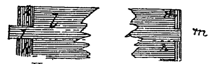
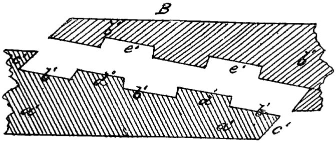


Fig 5



Joint for Horizontal with Vertical Piece



B

Fig 3

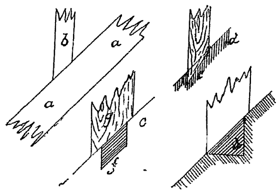
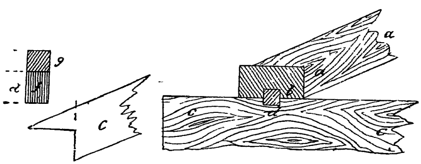


Fig 6—Junction of Vertical with Oblique Pieces

C

Fig 4—Keys and Tables of Scarf Joints



Fig, 7—Rafter, with Wall-Plate and Tie-Beam

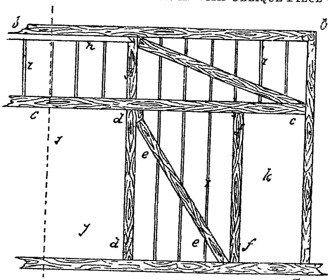


Fig 8—Framed and Braced Partition

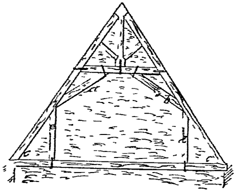


FIG 1

GOTHIC OF ROOF

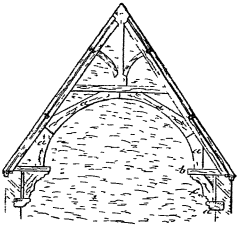


FIG 2

HIGH PITCHED TRUSSES

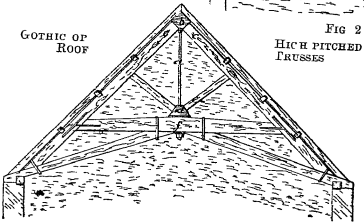


FIG. 3

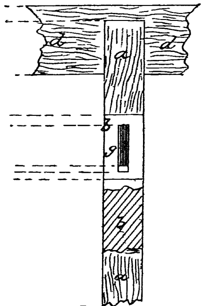


FIG. 4

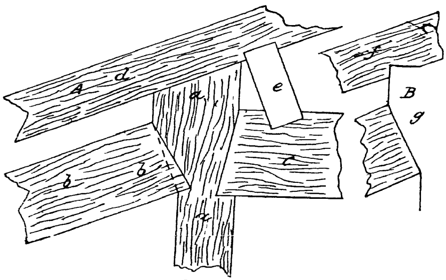


FIG 6

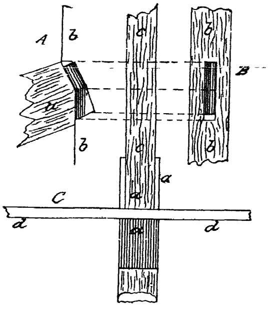


FIG 5

VARIOUS FORMS OF JOINTS IN ROOFS AND FLOORS (*see Text*)

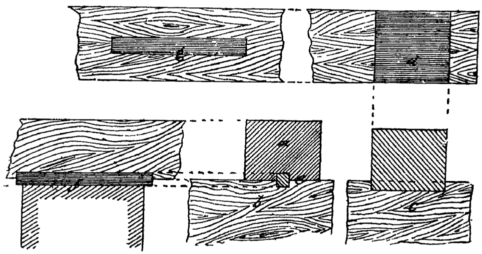


FIG 7

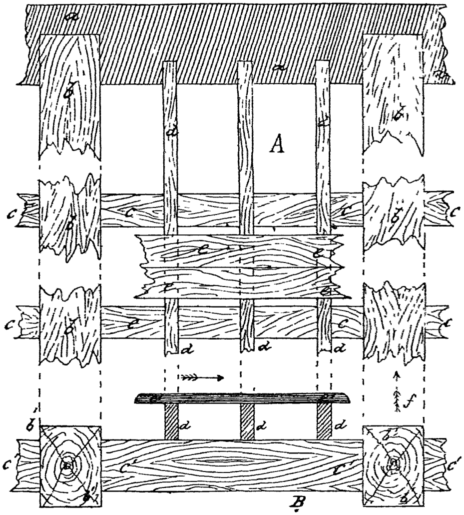


Fig 1

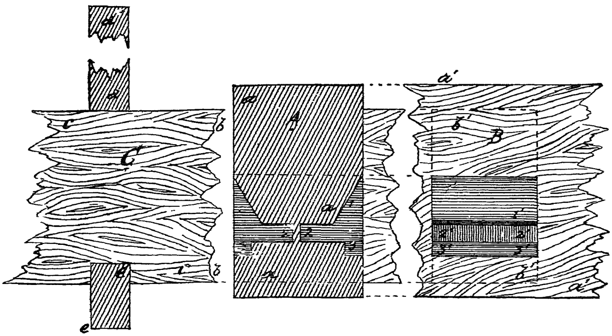


Fig 2

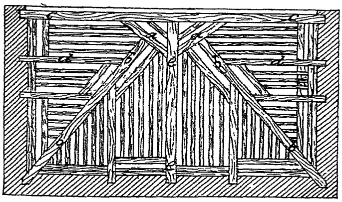


Fig 1

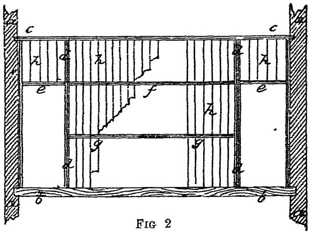


Fig 2

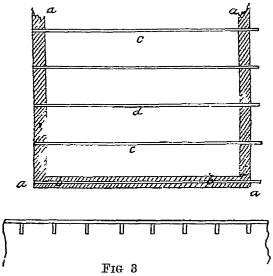


Fig 3

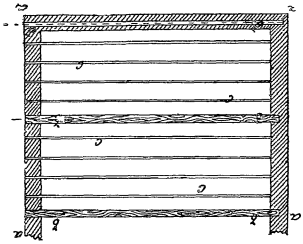


Fig 4

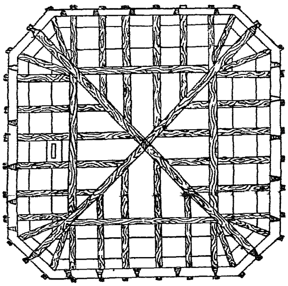


Fig 5

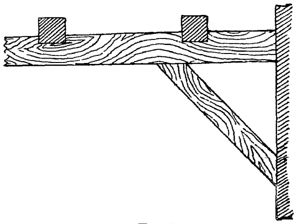


Fig 6

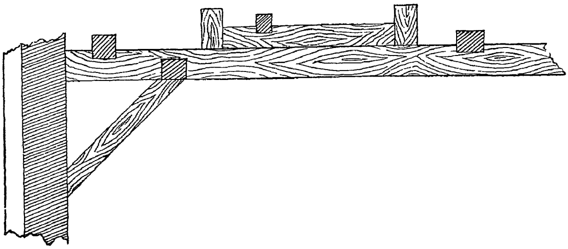


Fig 7

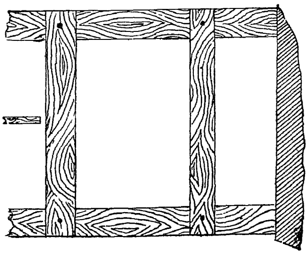


Fig 8

FLOOR CONSTRUCTION

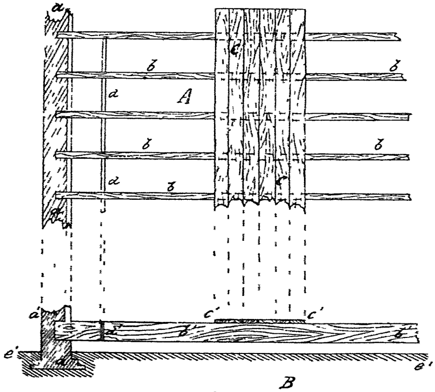


FIG 1

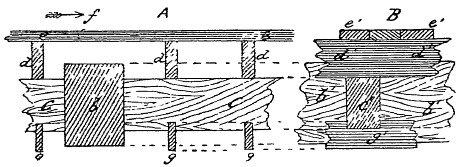


FIG 2.

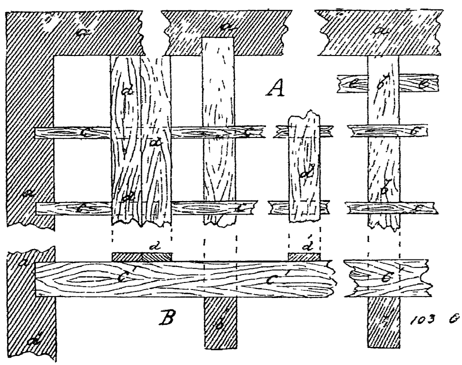


FIG 3

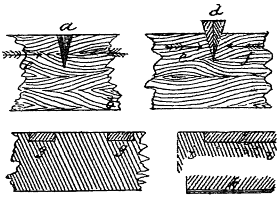


Fig 1

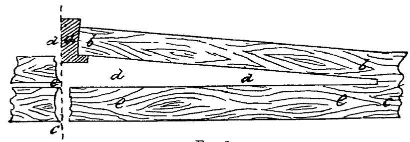


Fig 2

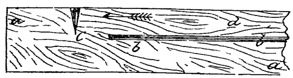


Fig 3

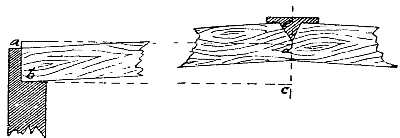


Fig 4

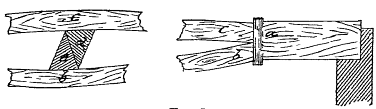


Fig 5

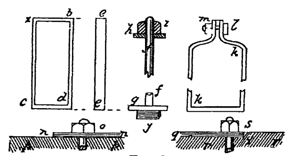


Fig 6

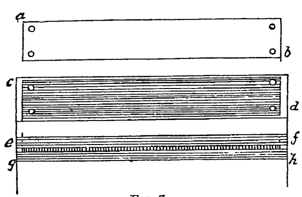


Fig 7

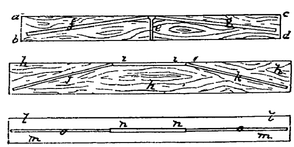


Fig 8

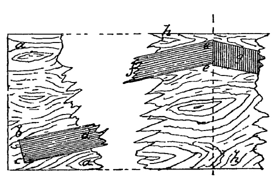


Fig 9

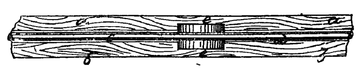


Fig 10

FLITCHED AND TRUSSED BEAMS

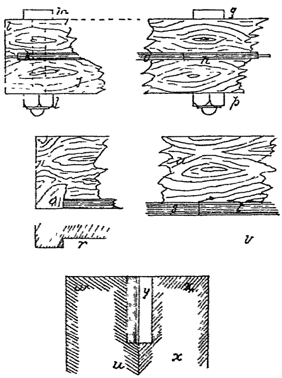


FIG 1.

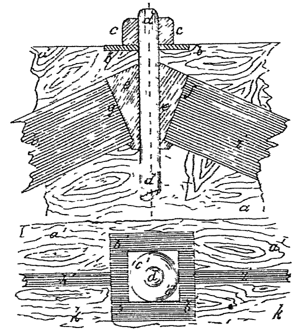


FIG. 2

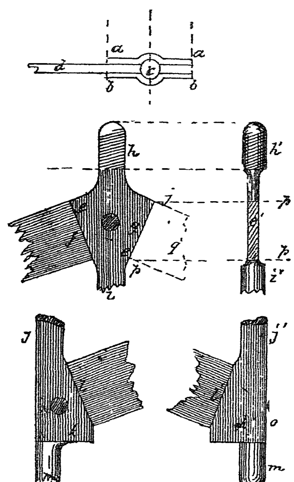


FIG 3

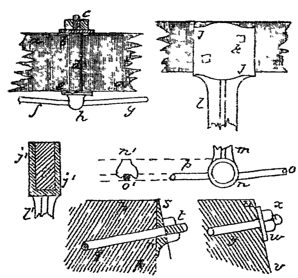


FIG 4

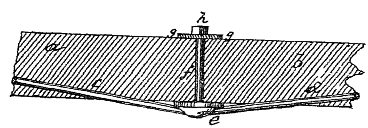


FIG 5

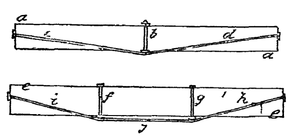


FIG 6

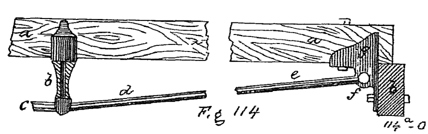


FIG 7

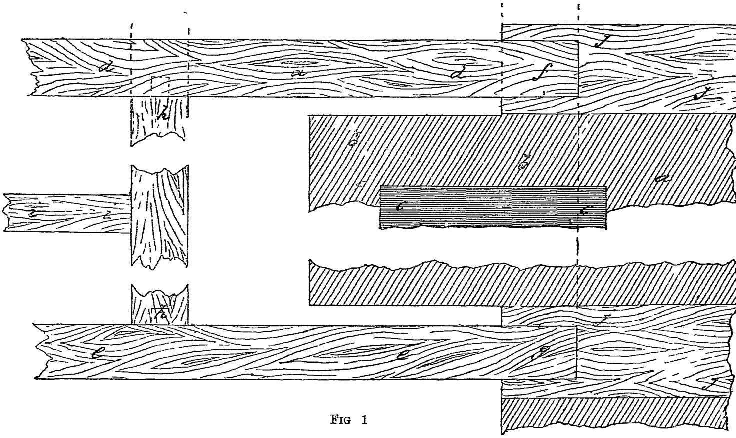


FIG 1

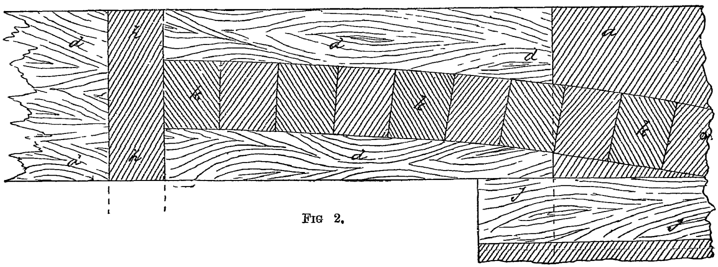


FIG 2.

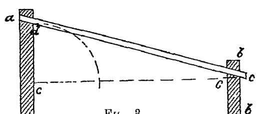


FIG 3

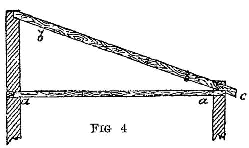


FIG 4

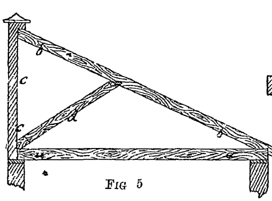


FIG 5

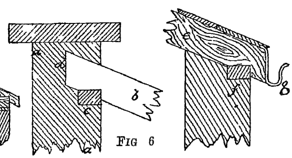


FIG 6

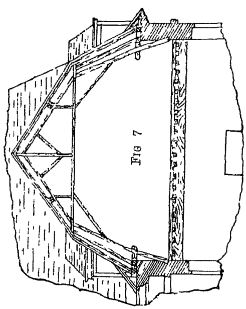


FIG 7

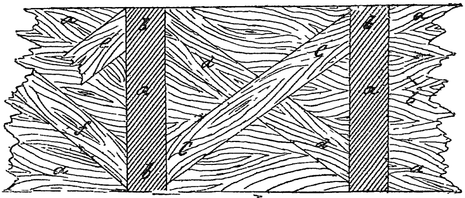


FIG 1

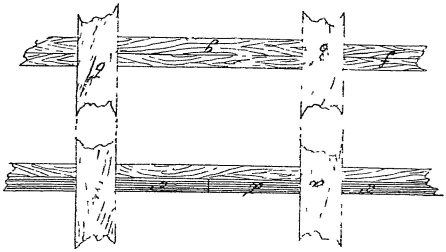


FIG 2

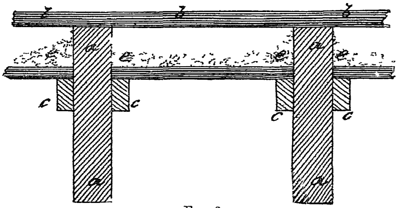


FIG 3

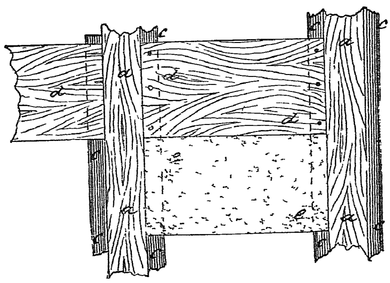


FIG 4

[Plate XI

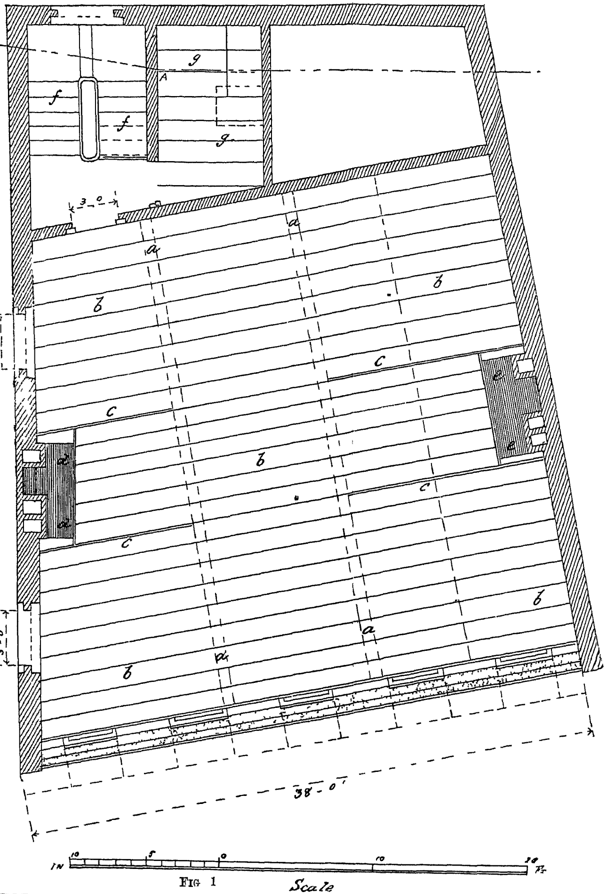


FIG 1

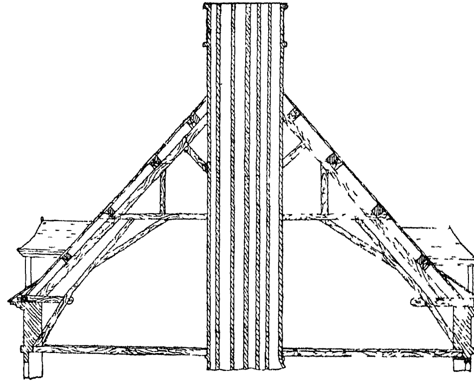


FIG 2

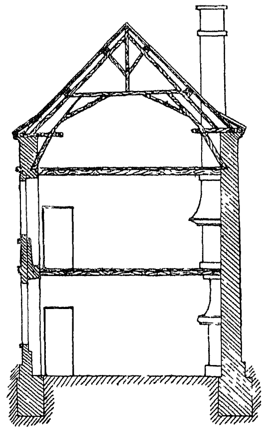


FIG 3

[Plate XII.

PARTITIONS

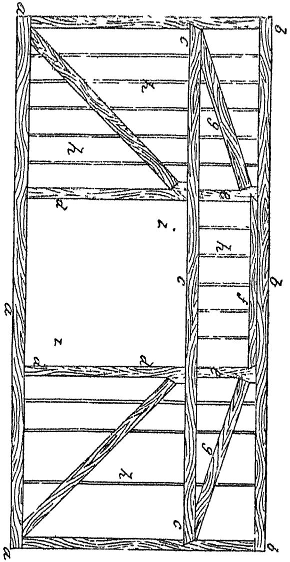


FIG 1

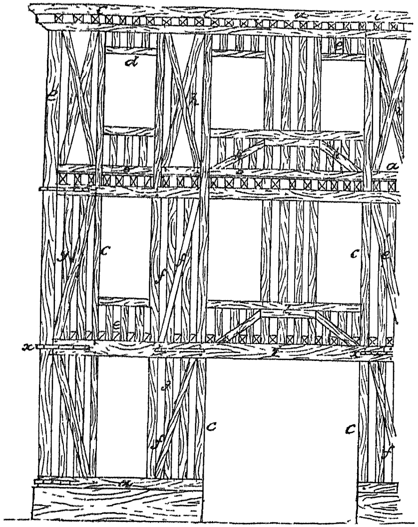


FIG 2

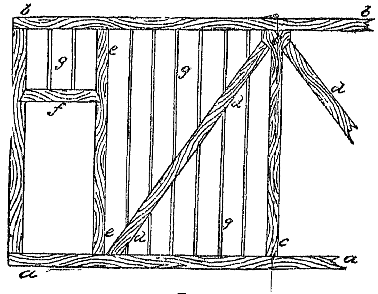


FIG 3

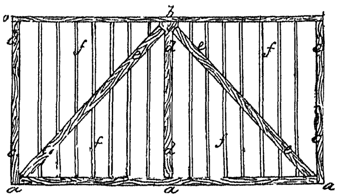


FIG 4

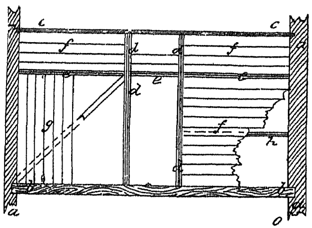


FIG 5

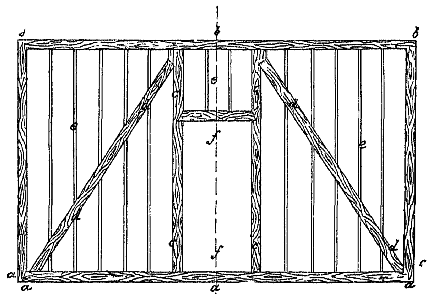
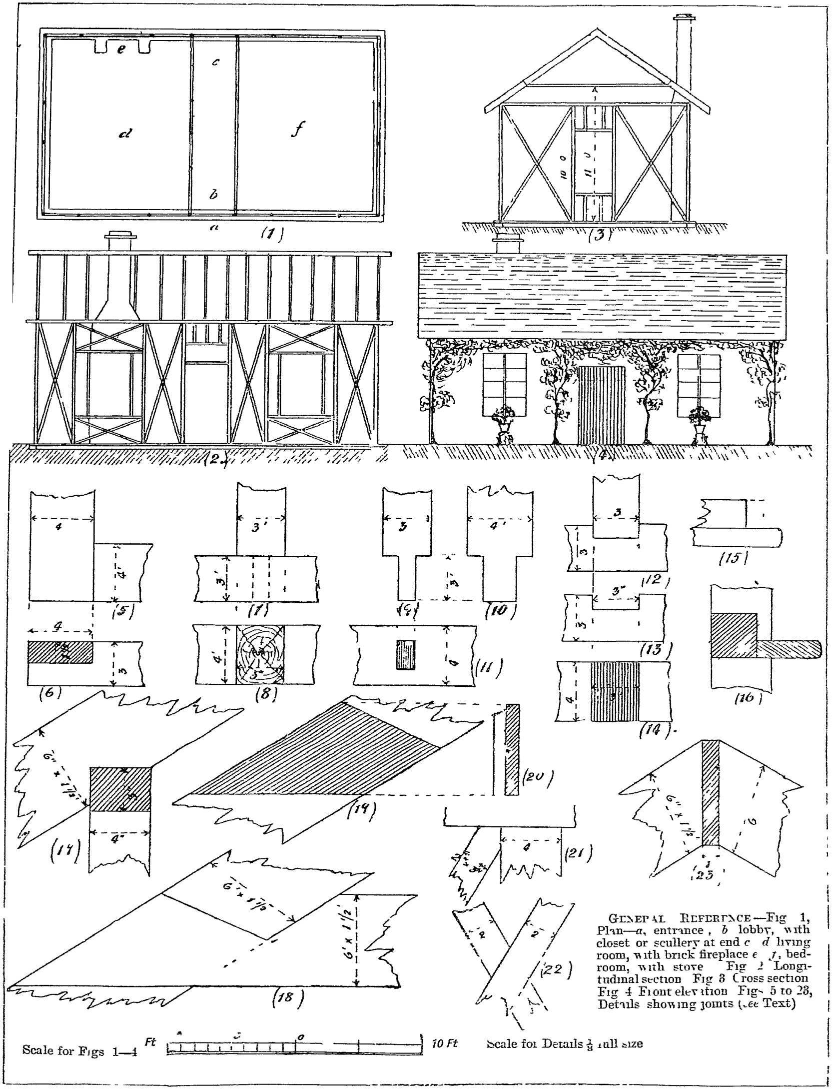


FIG 6

THE CARPENTER

TIMBER COTTAGE—OR "FRAMED-HOUSE"—FOR COLONISTS AND EMIGRANTS



GENERAL REFERENCE.—Fig 1, Plan—*a*, entrance, *b* lobby, with closet or scullery at end *c* *d* living room, with brick fireplace *e* *f*, bedroom, with stove Fig 2 Longitudinal section Fig 3 Cross section Fig 4 Front elevation Figs 5 to 23, Details showing joints (see Text)

Scale for Figs 1—4 Ft 10 Ft Scale for Details $\frac{1}{3}$ full size

[Plate XIV

SECTION AND PLAN OF ROOF OF HOUSE, SHOWING ARRANGEMENT OF TIMBERS

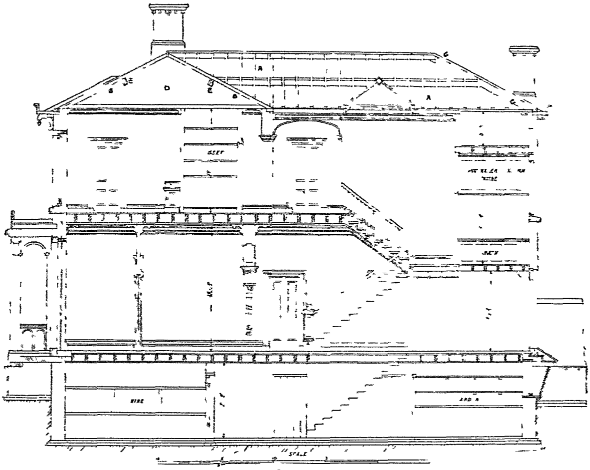


FIG 1

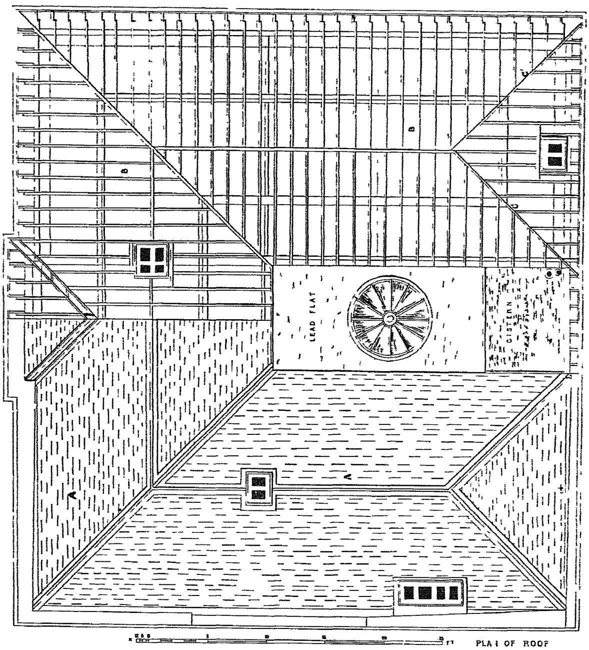


FIG 2

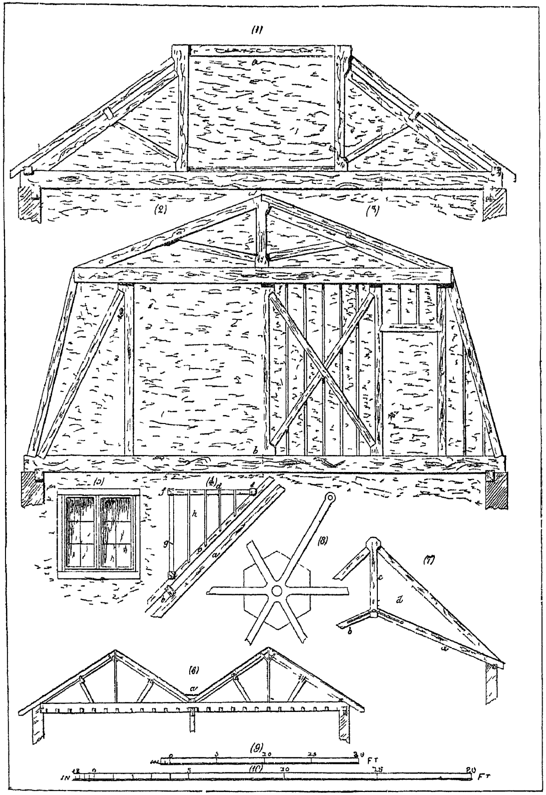


Fig 1

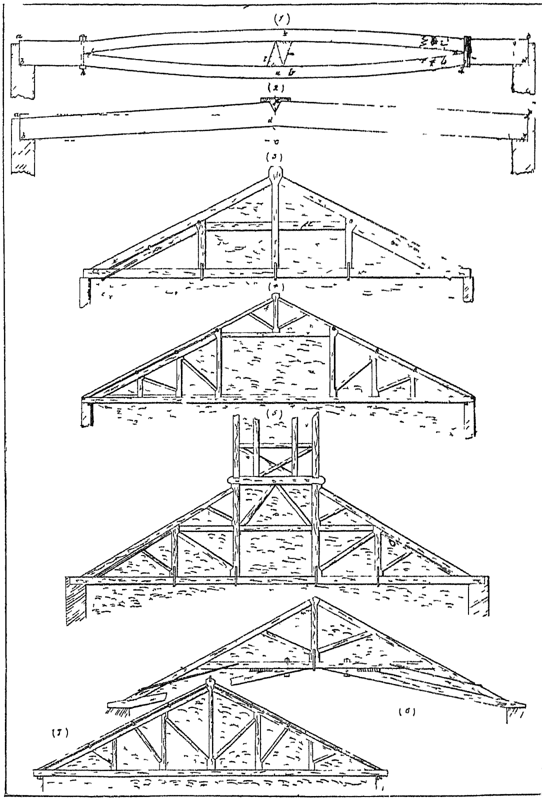
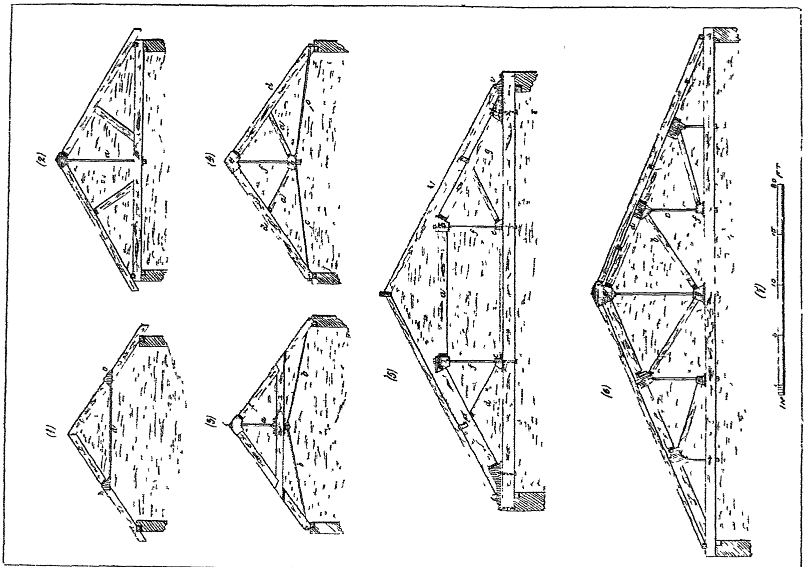
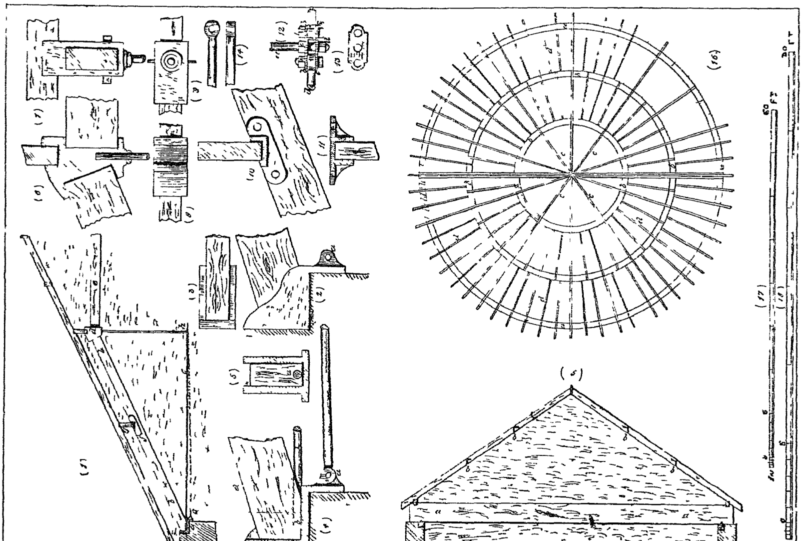


Fig 2





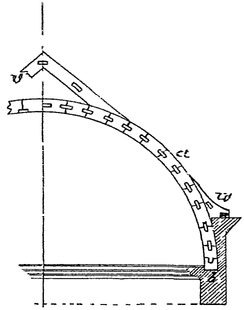


FIG 1

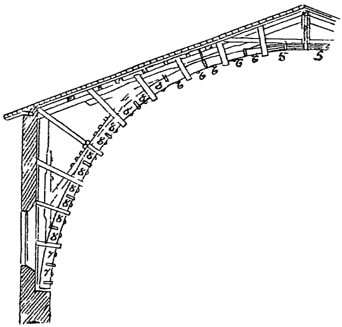


Fig 2

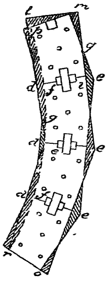


FIG 3

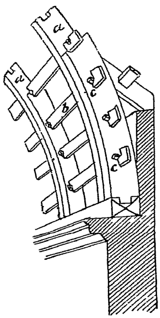


FIG 4

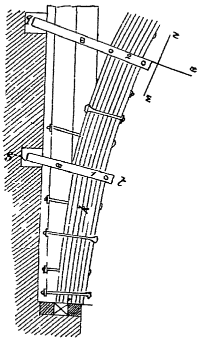


FIG 5

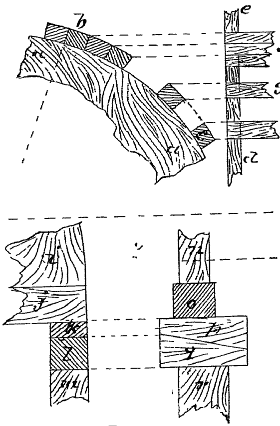


FIG 6

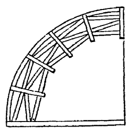


FIG 7

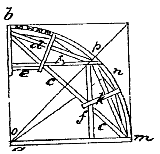


FIG 8

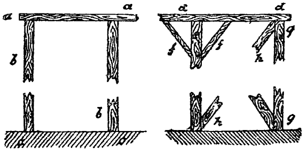


FIG 9

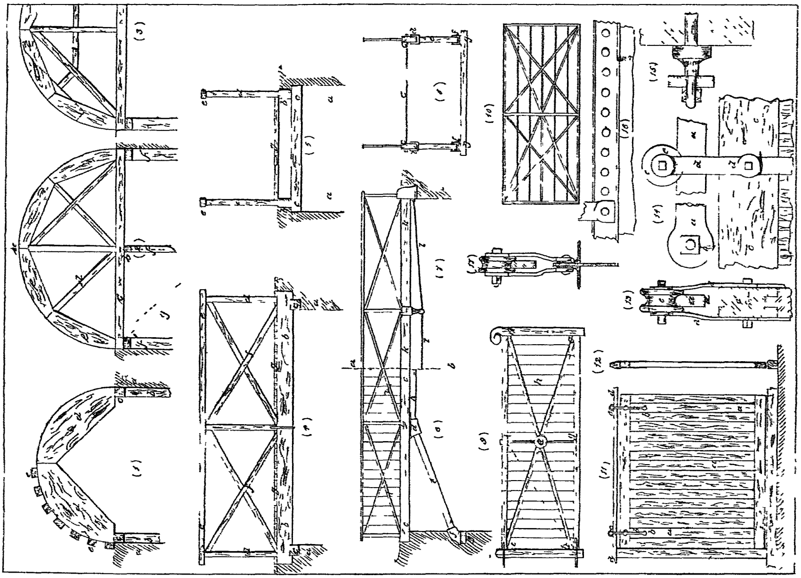


Fig 2

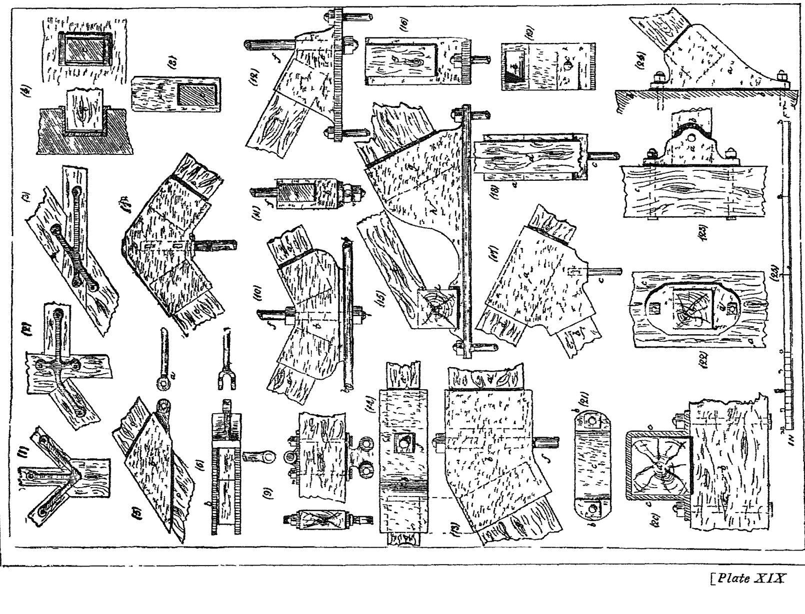
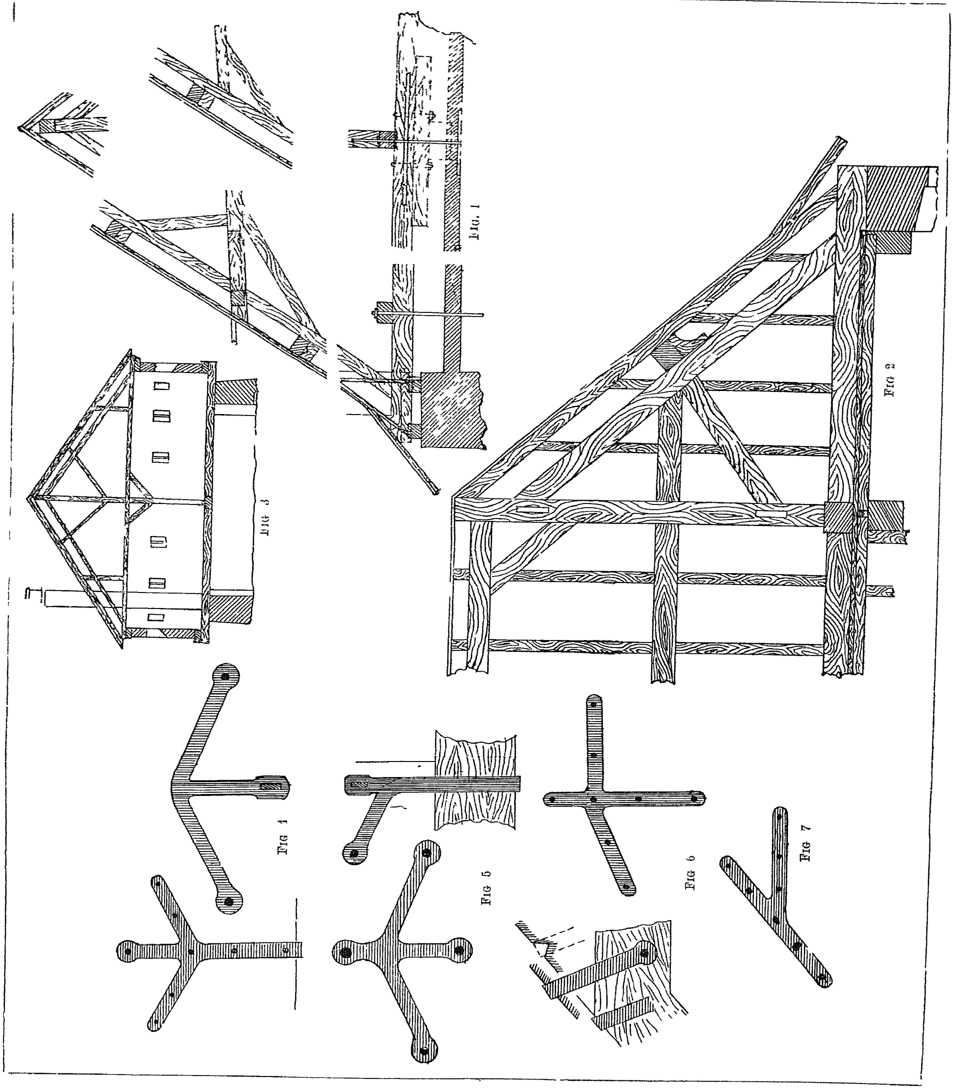
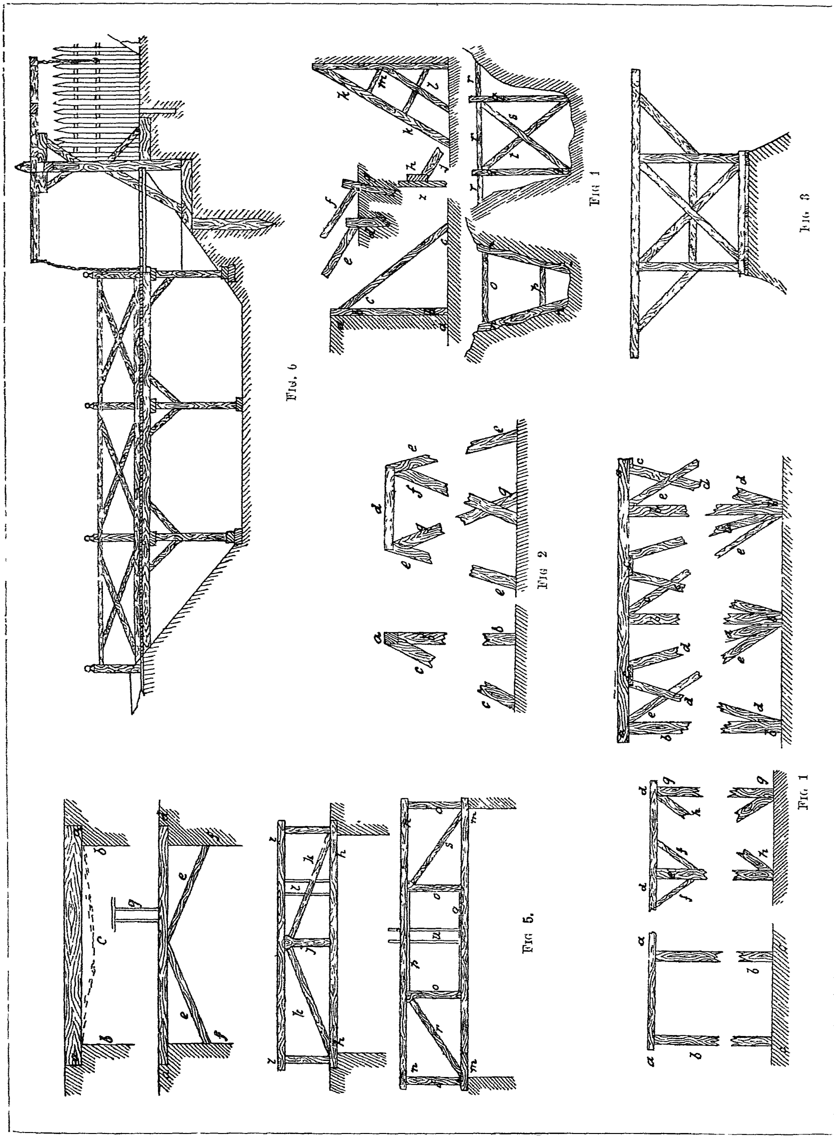


Fig 1

[Plate XX





[Plate XXI

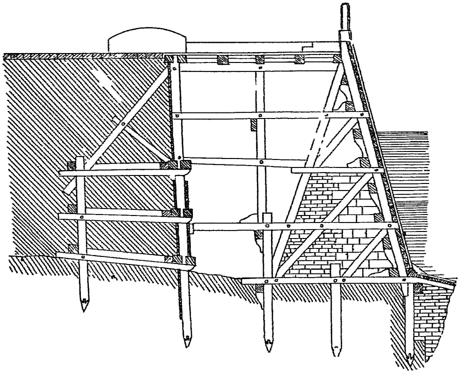


FIG I

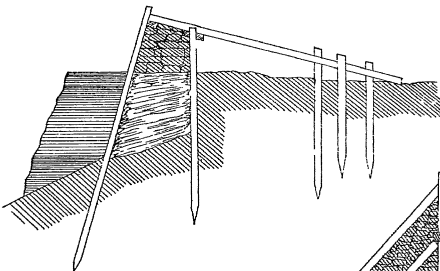


FIG 2

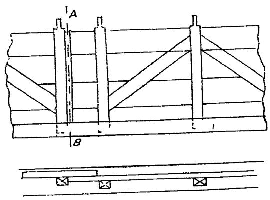


FIG. 3

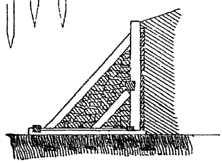


FIG 4

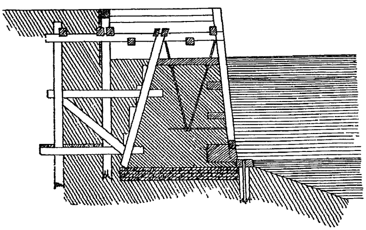


FIG 5

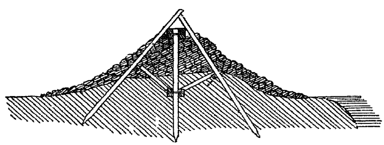


FIG 6

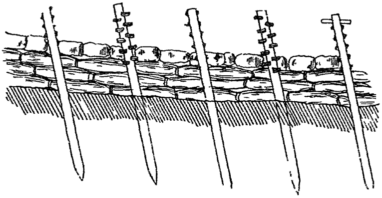


Fig 1

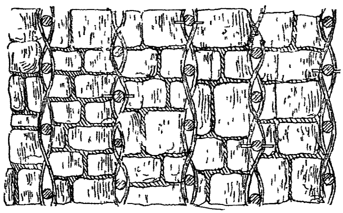


Fig 2

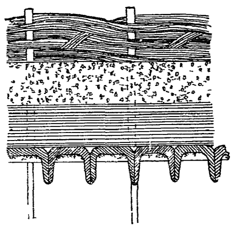


Fig 3

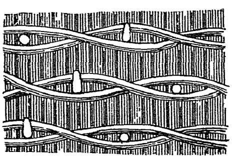


Fig 4.

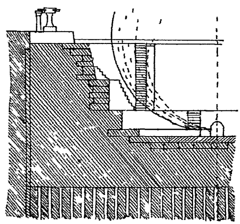


Fig 5

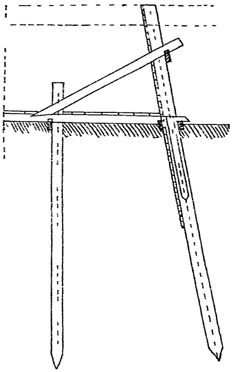


Fig 1

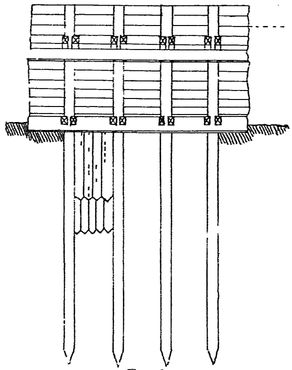


Fig 2

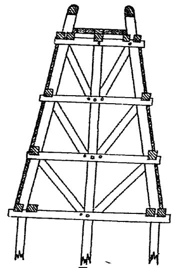
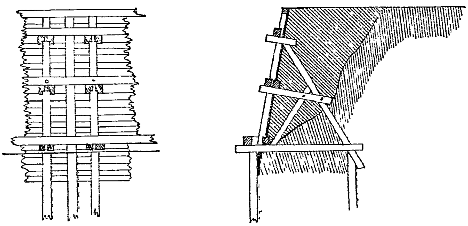


Fig 3



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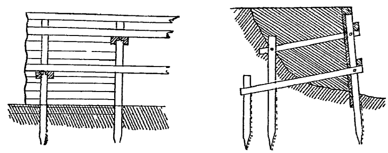


Fig 5

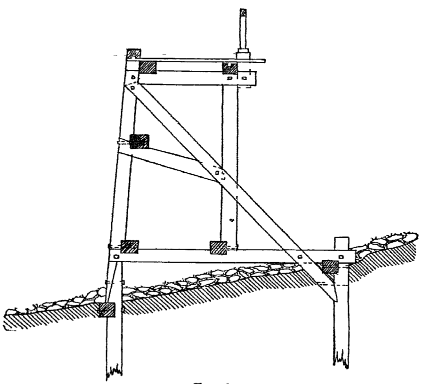


Fig 6

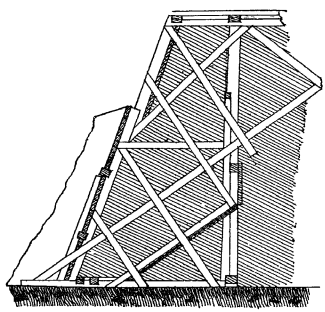


Fig 7

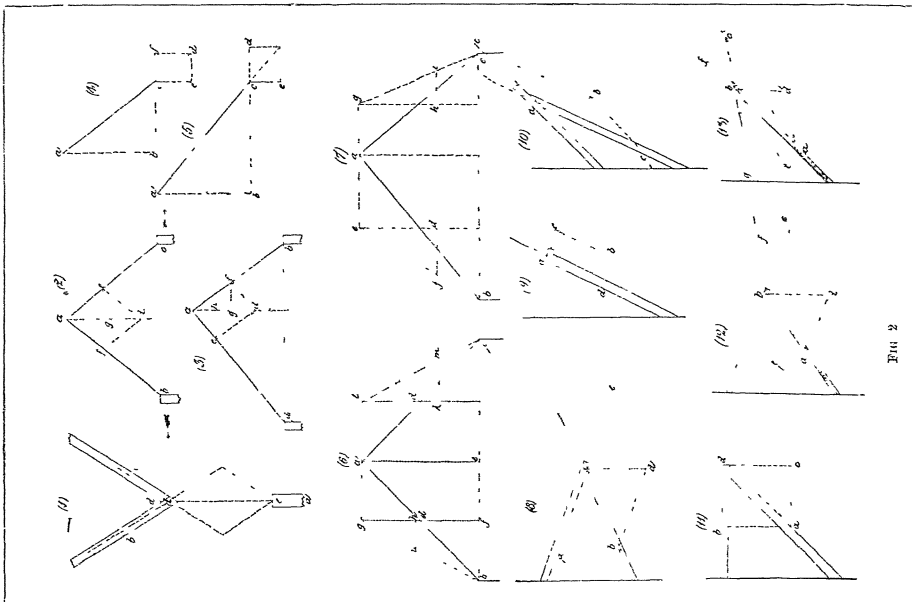


FIG 2

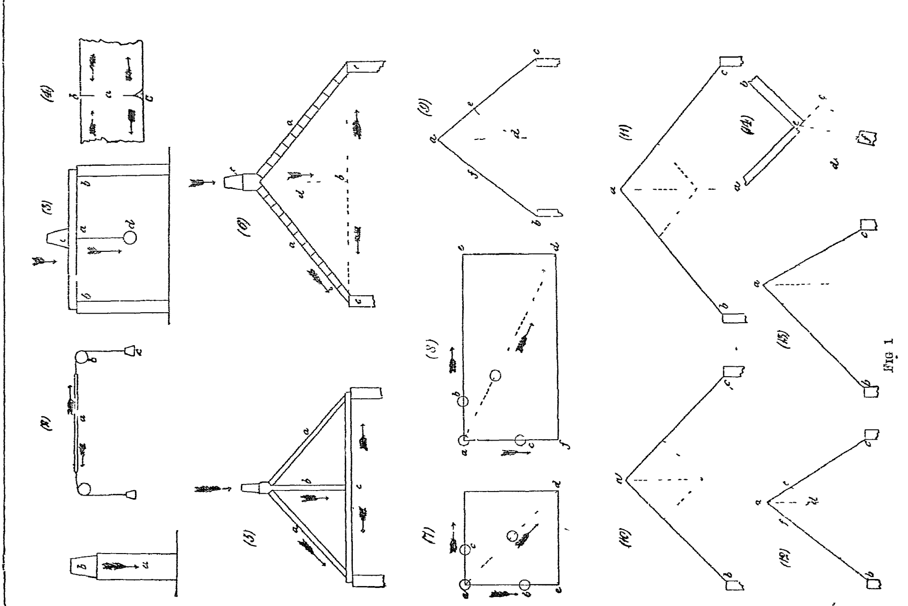
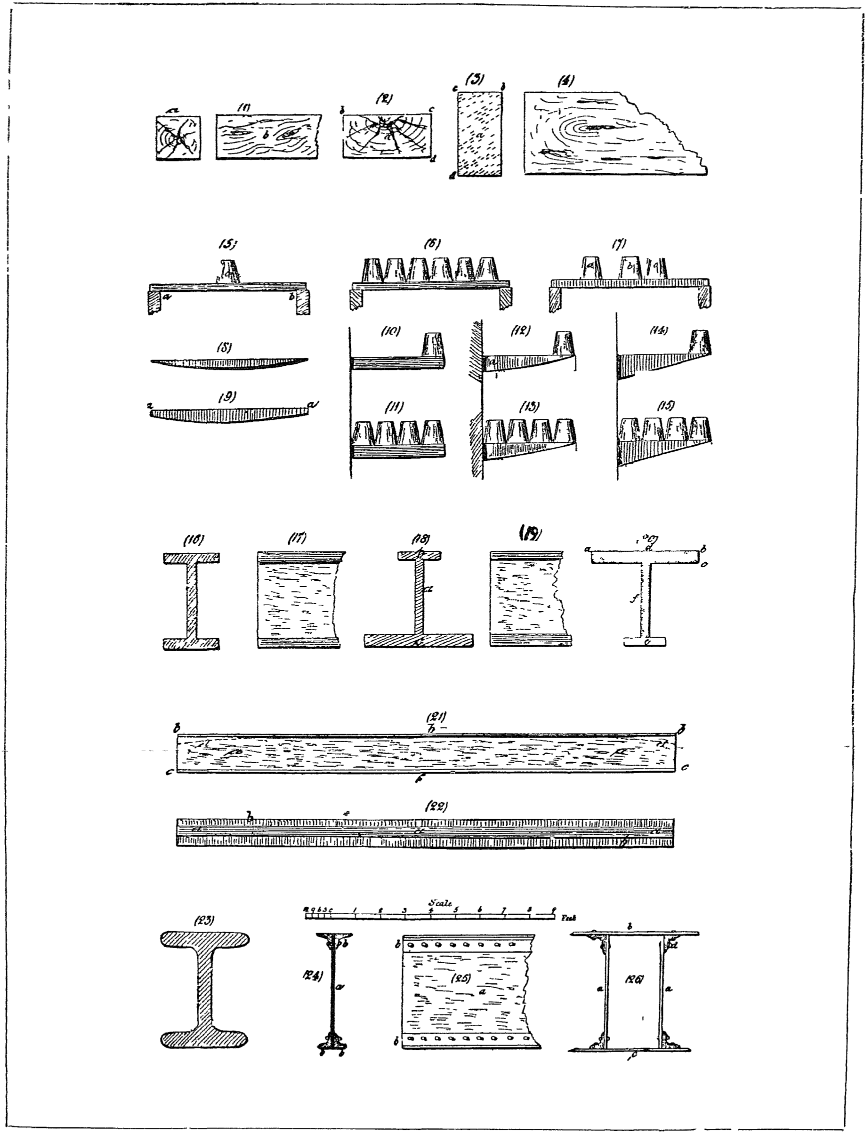


FIG 1


(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
(15)
(16)
(17)
(18)
(19)
(21)
(22)
(23)
(24)
(25)
(26)
Scale
Feet

[Plate XXVI

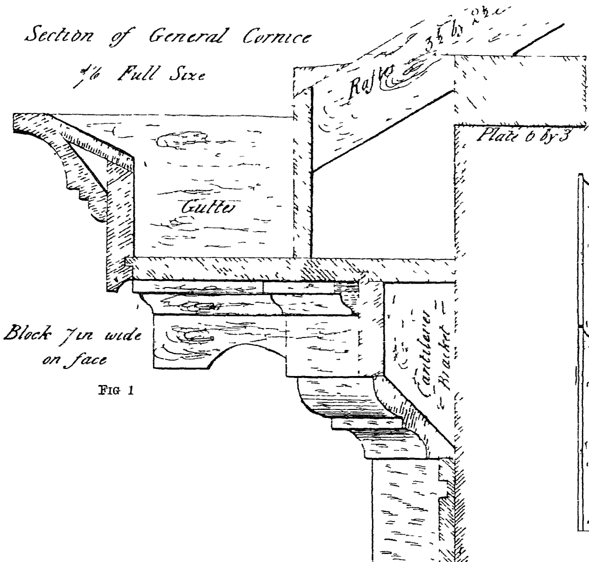


FIG 1

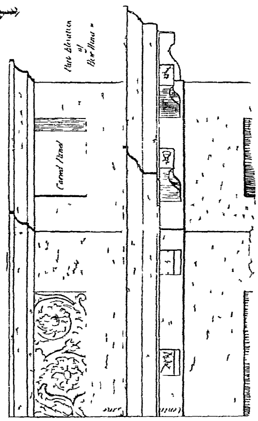


FIG 2

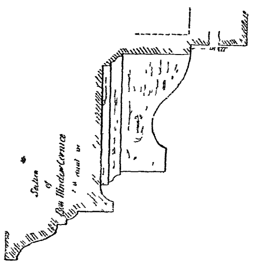
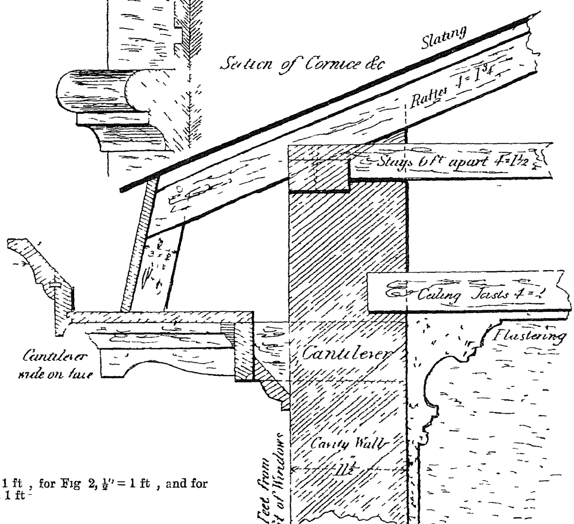


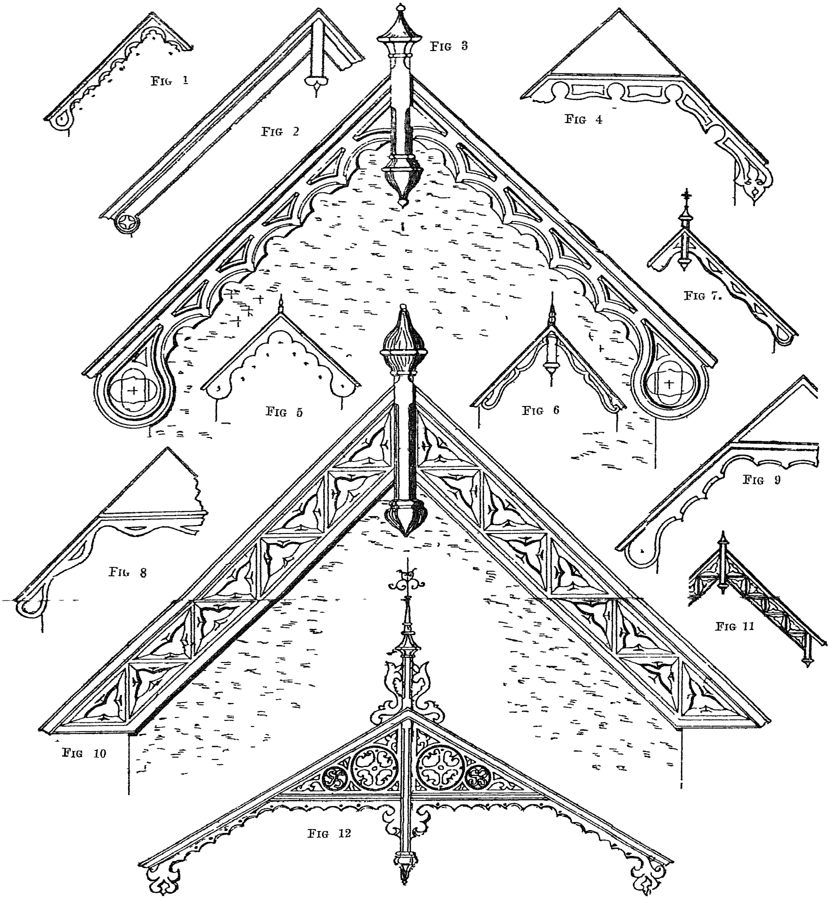
FIG 3.



Scale for Fig 1, 2″ = 1 ft., for Fig 4 1″ = 1 ft , for Fig 2, ½″ = 1 ft , and for Fig 3, 1½″ = 1 ft

FIG 4

SUGGESTIONS FOR BARGE BOARDS—DOMESTIC ARCHITECTURE



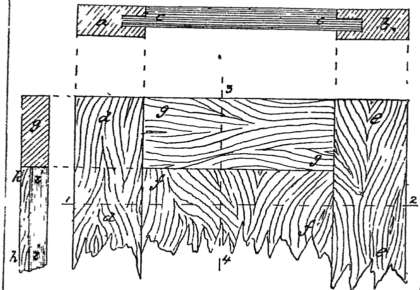


Fig 1

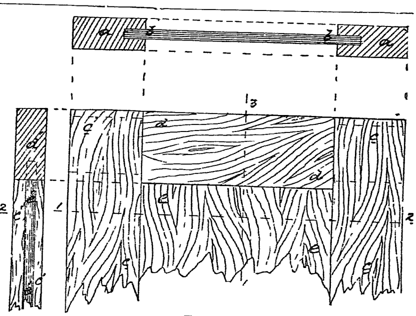


Fig 2

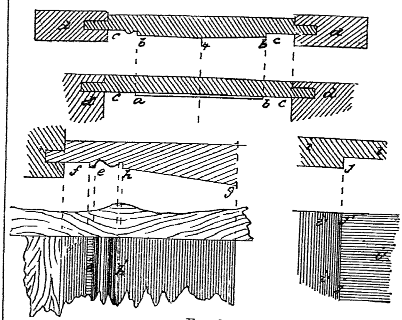


Fig 3

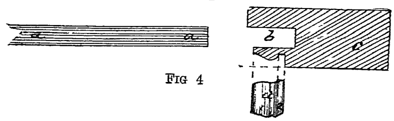


Fig 4

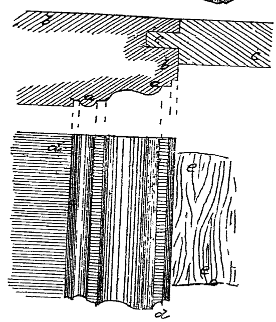


Fig 5

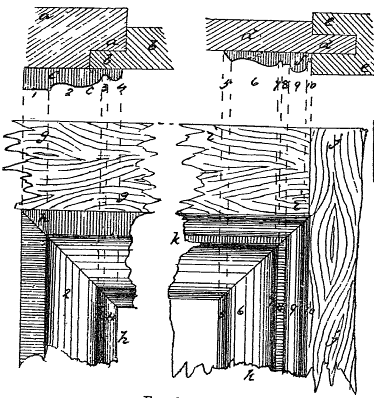


Fig 6

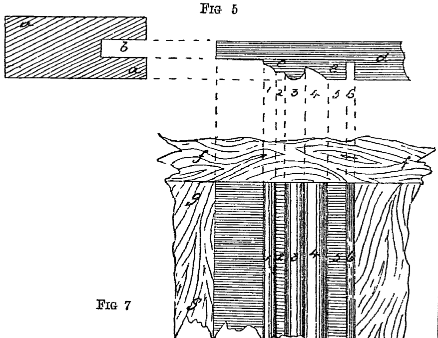


Fig 7

Various Forms of Panels and Panel Mouldings

[Plate XXIX

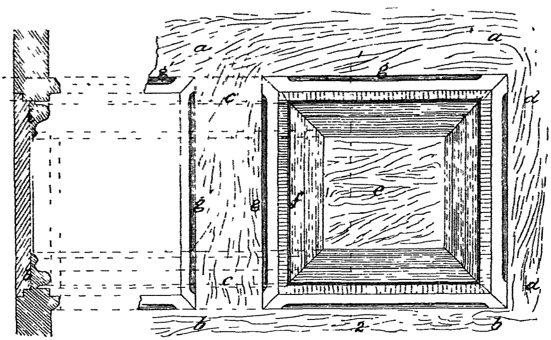


FIG 1

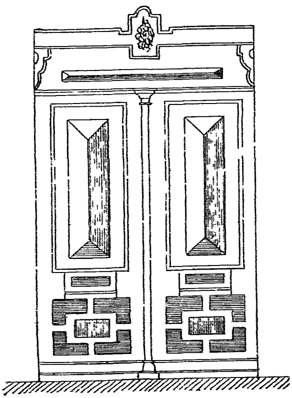


FIG 2

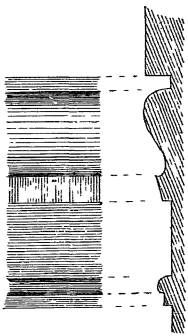


FIG 3

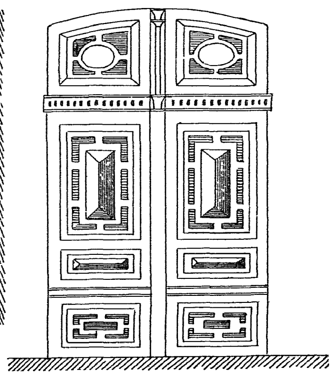


FIG 4

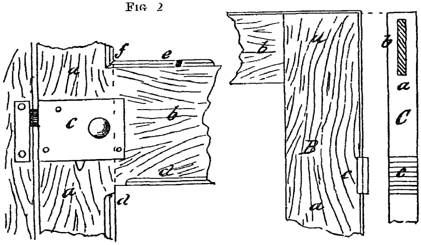


FIG 5

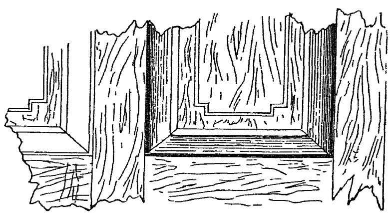


FIG 6

DOORS, PANELS, AND DETAILS OF DOORS

[Plate XXX

PANELLED DOOR CASING AND ARCHITRAVE IN PART ELEVATION AND PLAN (FIGS 1 AND 2), WITH DETAILS OF STYLES AND RAILS (FIGS 3 AND 4), RAISED PANEL WORK, CROSS SECTIONS (FIGS 5 AND 6)

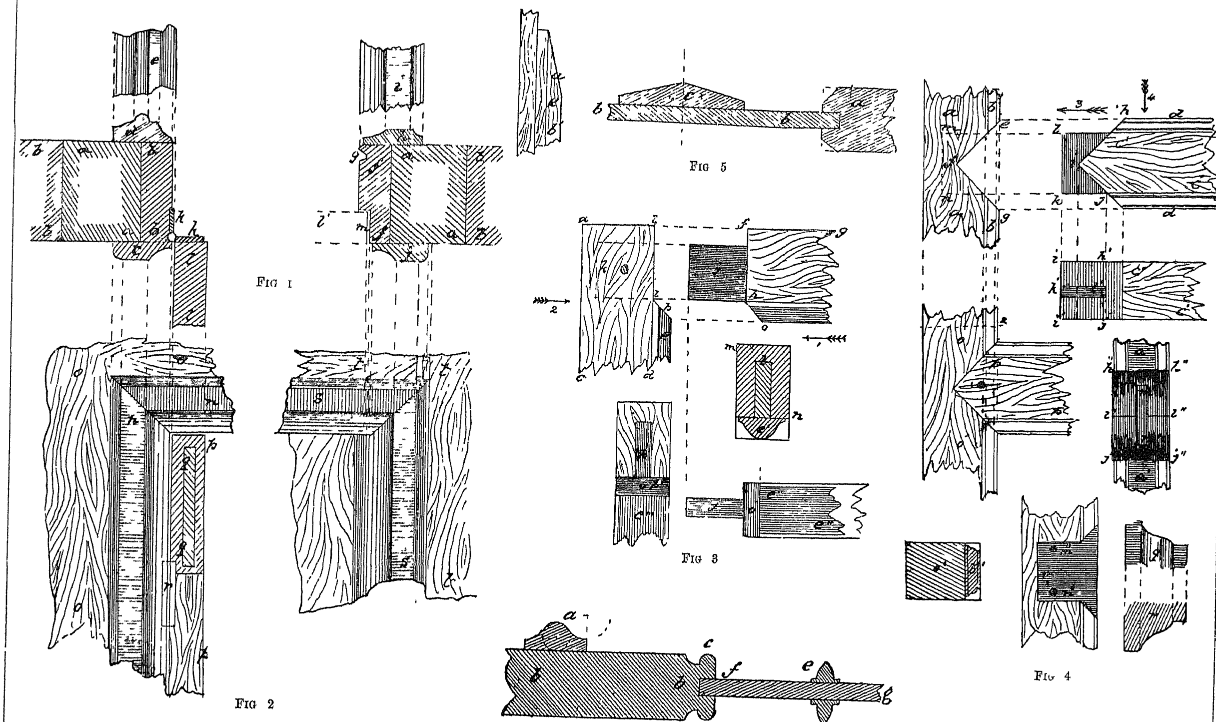


FIG 1

FIG 2

FIG 3

FIG 4

FIG 5

FIG 6

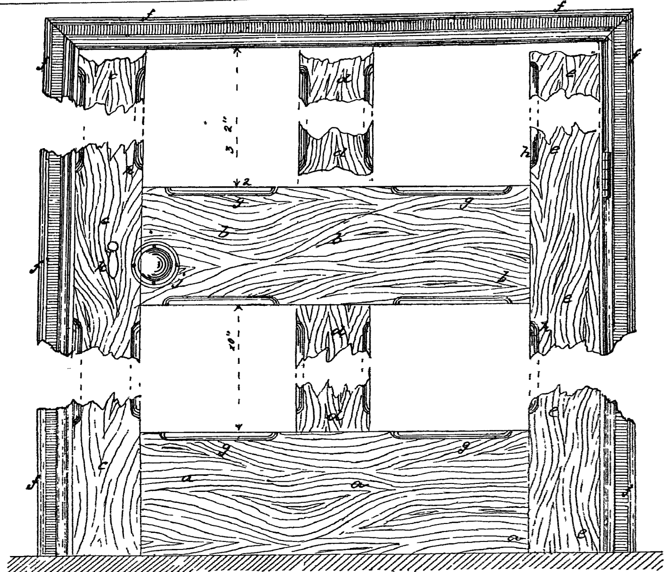


FIG 1

PART OF FOUR-PANELLED DOOR, AND DETAILS

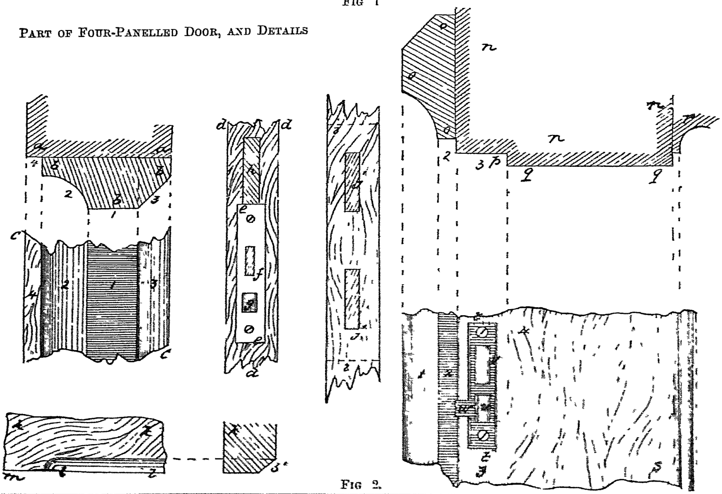


FIG 2.

WINDOW CONSTRUCTION

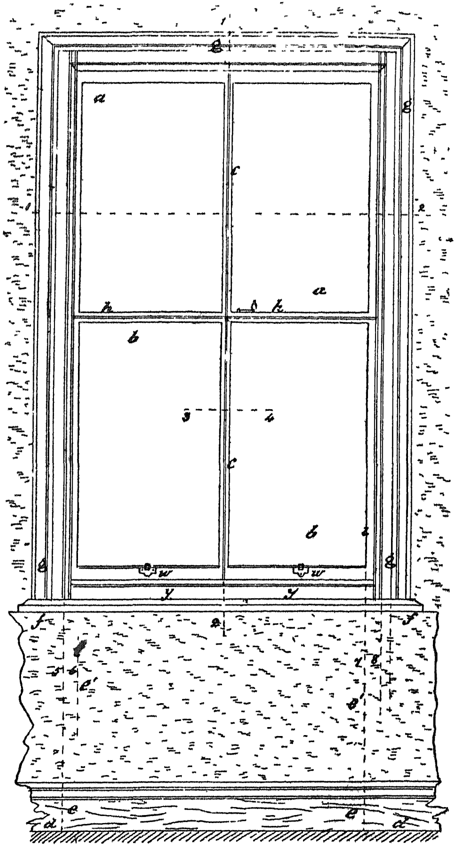


FIG 1.

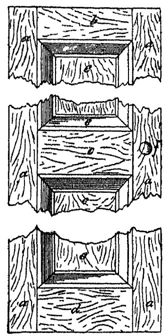


FIG 2

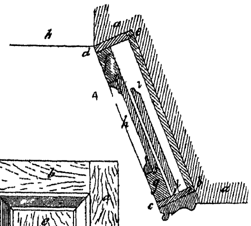


FIG 3

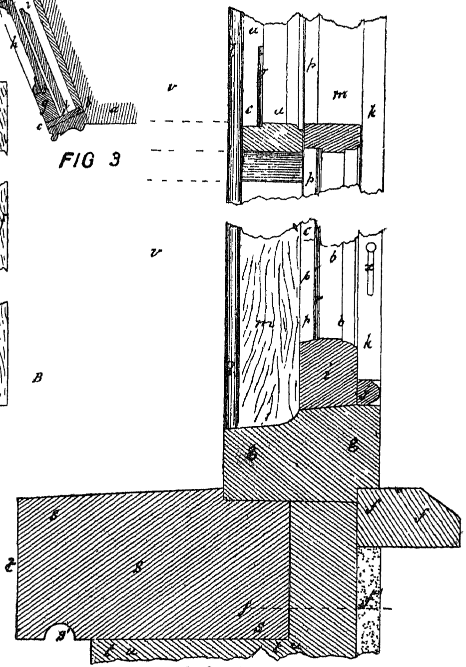


FIG 4

DETAILS OF WINDOW CONSTRUCTION

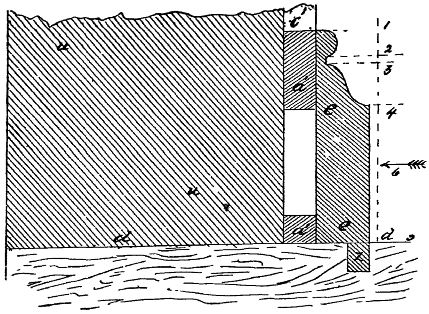


FIG 1

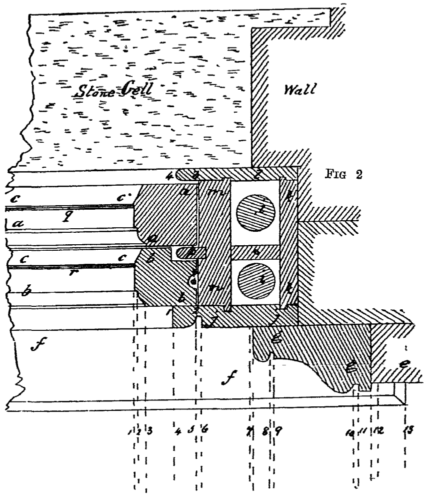


FIG 2

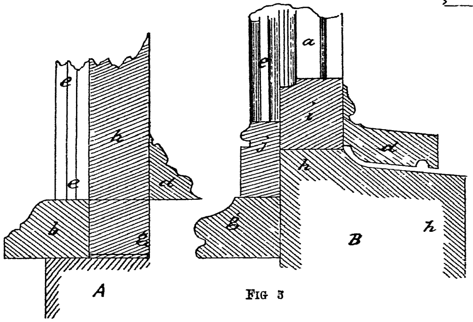


FIG 3

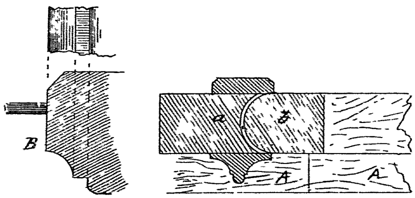


FIG 4

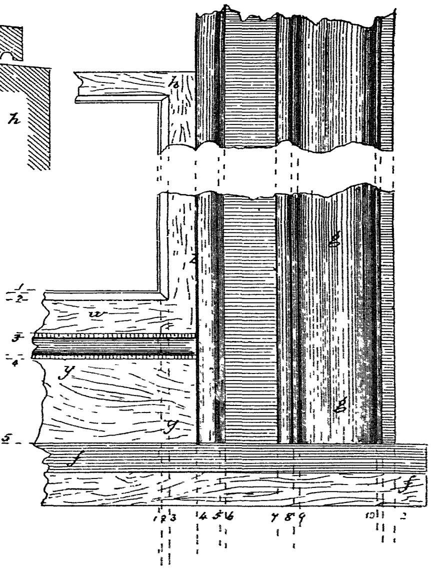


FIG 5.

WINDOW CONSTRUCTION

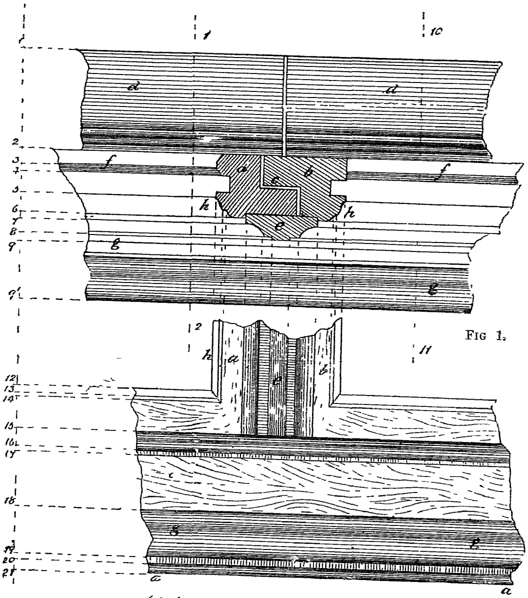


FIG 1.

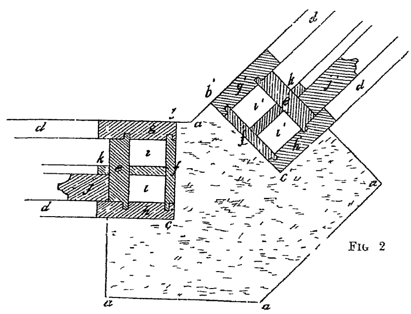


FIG 2

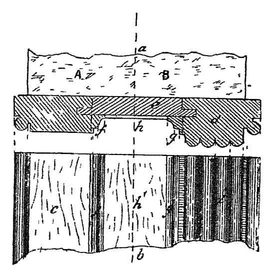


FIG 3

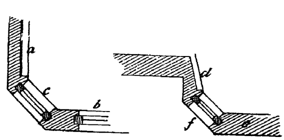


FIG 4

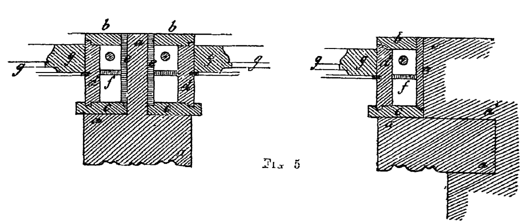


FIG 5

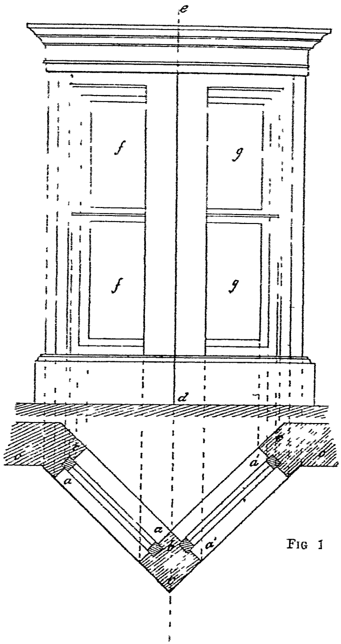


FIG 1

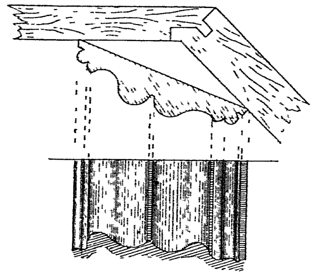


FIG 2

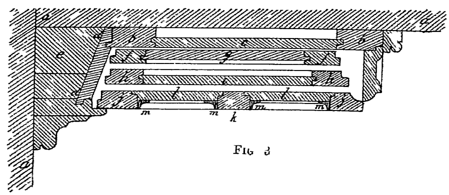


FIG 3

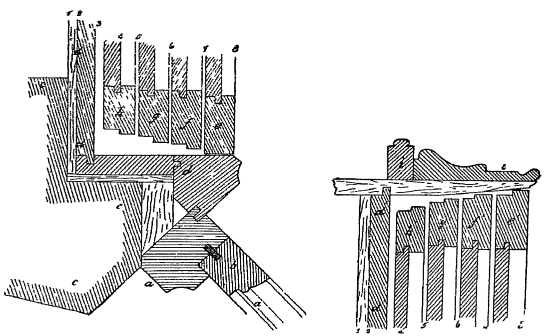


FIG 4

WINDOW CONSTRUCTION

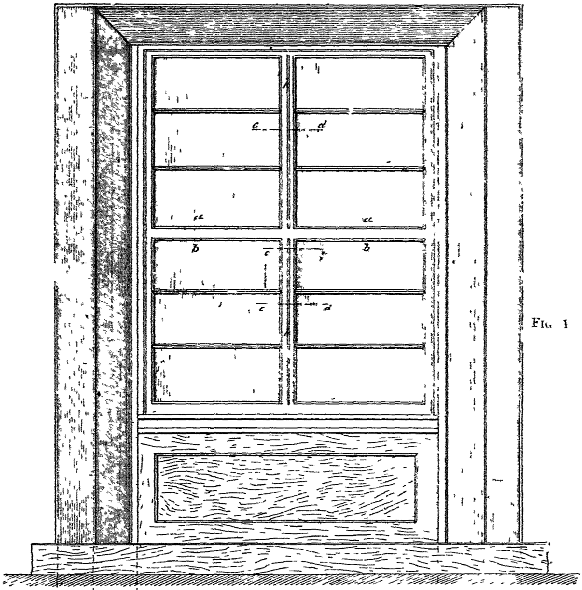


FIG. 1

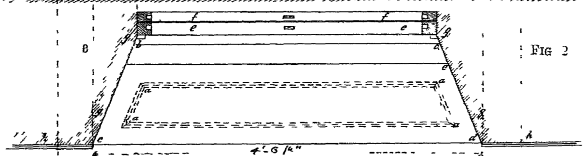


FIG. 2

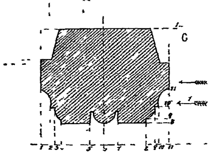


FIG. 3.

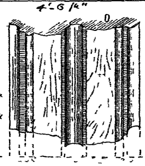


FIG. 4

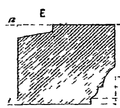


FIG. 5

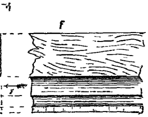
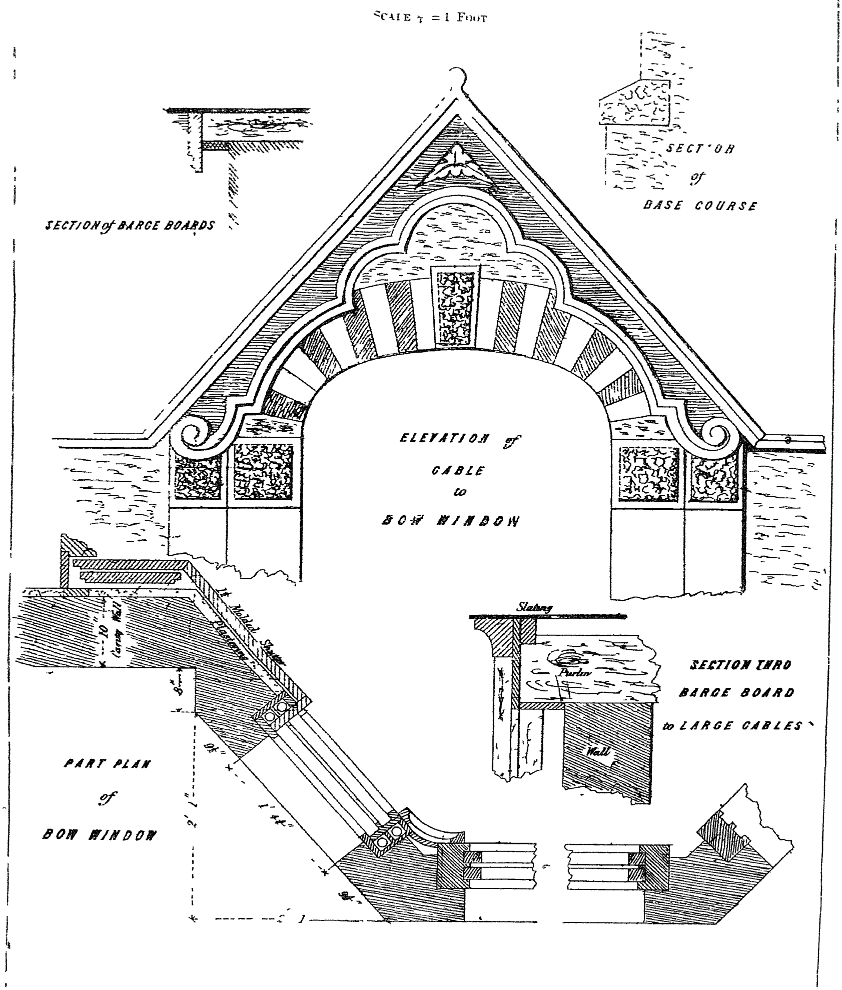
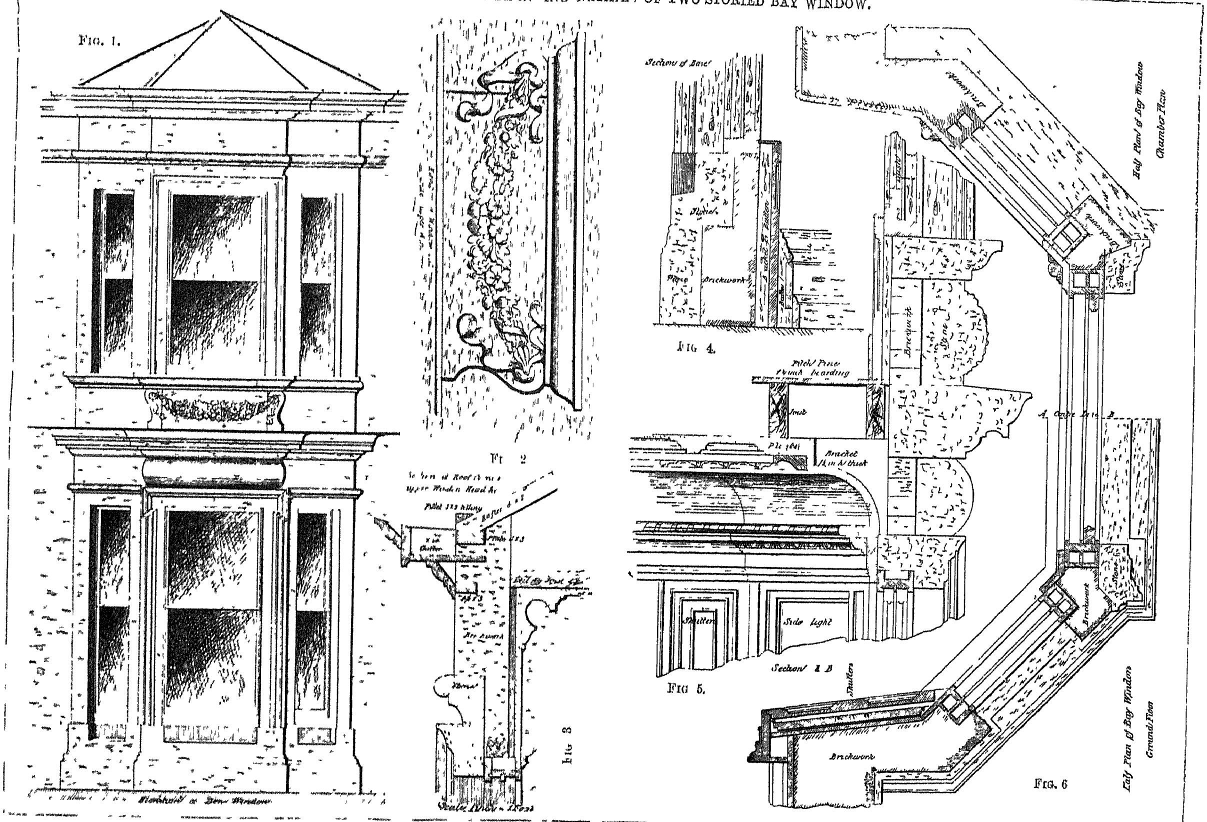


FIG. 6

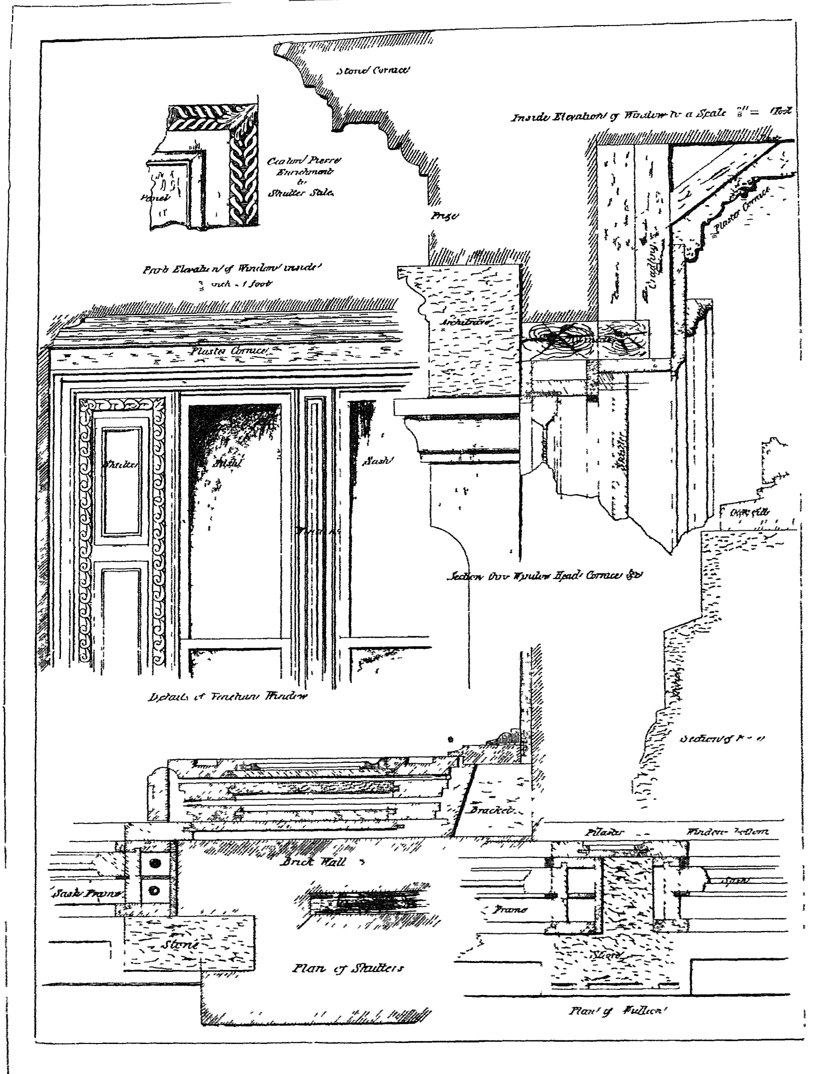

SCALE ½ = 1 FOOT
SECTION of BARGE BOARDS
SECT'ON of BASE COURSE
ELEVATION of GABLE to BOW WINDOW
Slating
Purlin
Wall
SECTION THRO BARGE BOARD to LARGE GABLES
PART PLAN of BOW WINDOW
Cavity Wall
Plastering

ELEVATION AND PLAN AND DETAILS OF TWO STORIED BAY WINDOW.



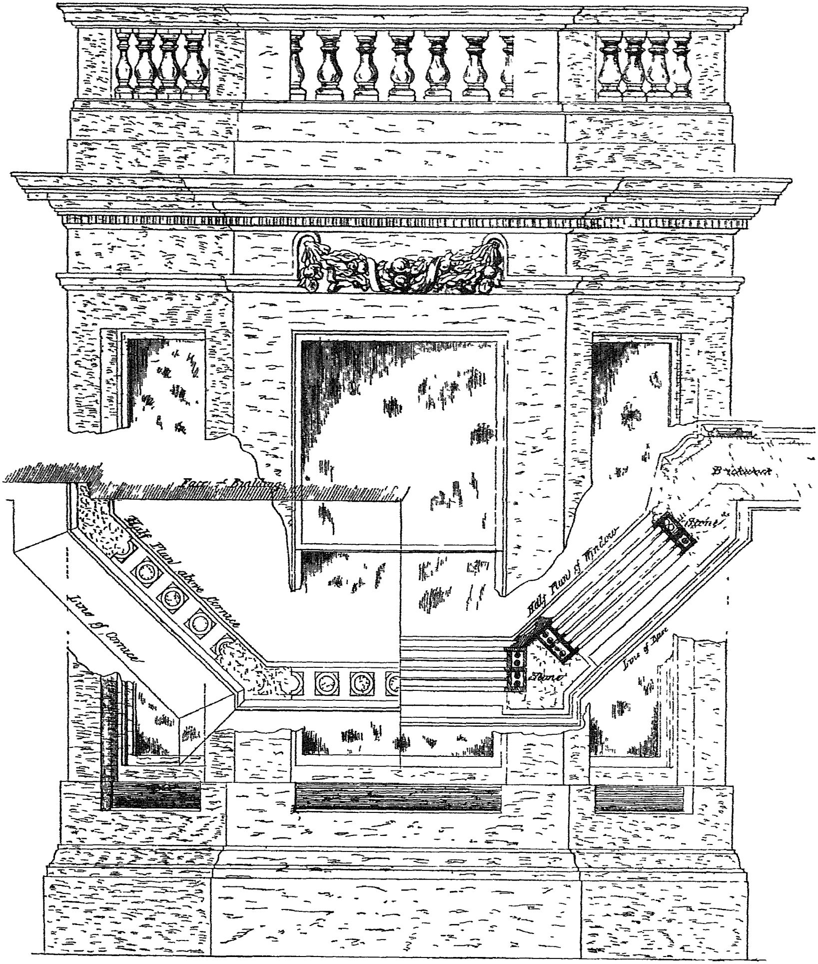
[Plate XXVIX

DETAILS OF VENETIAN WINDOW

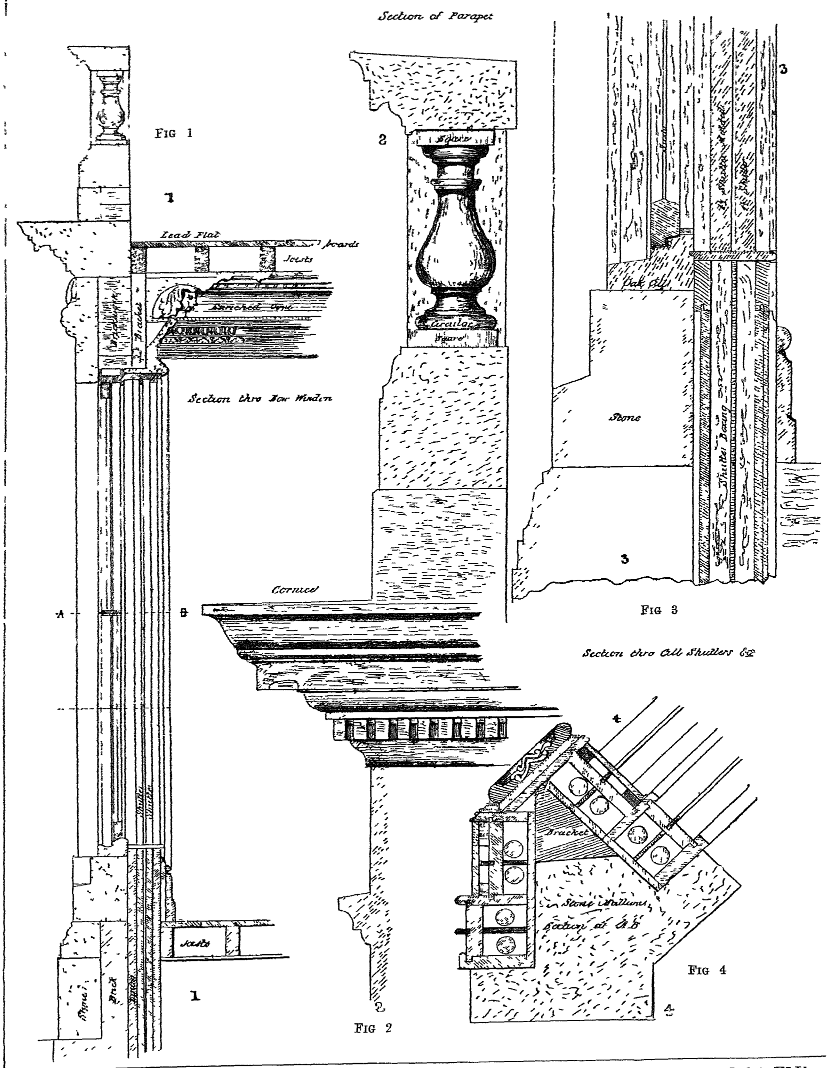


[Plate XL

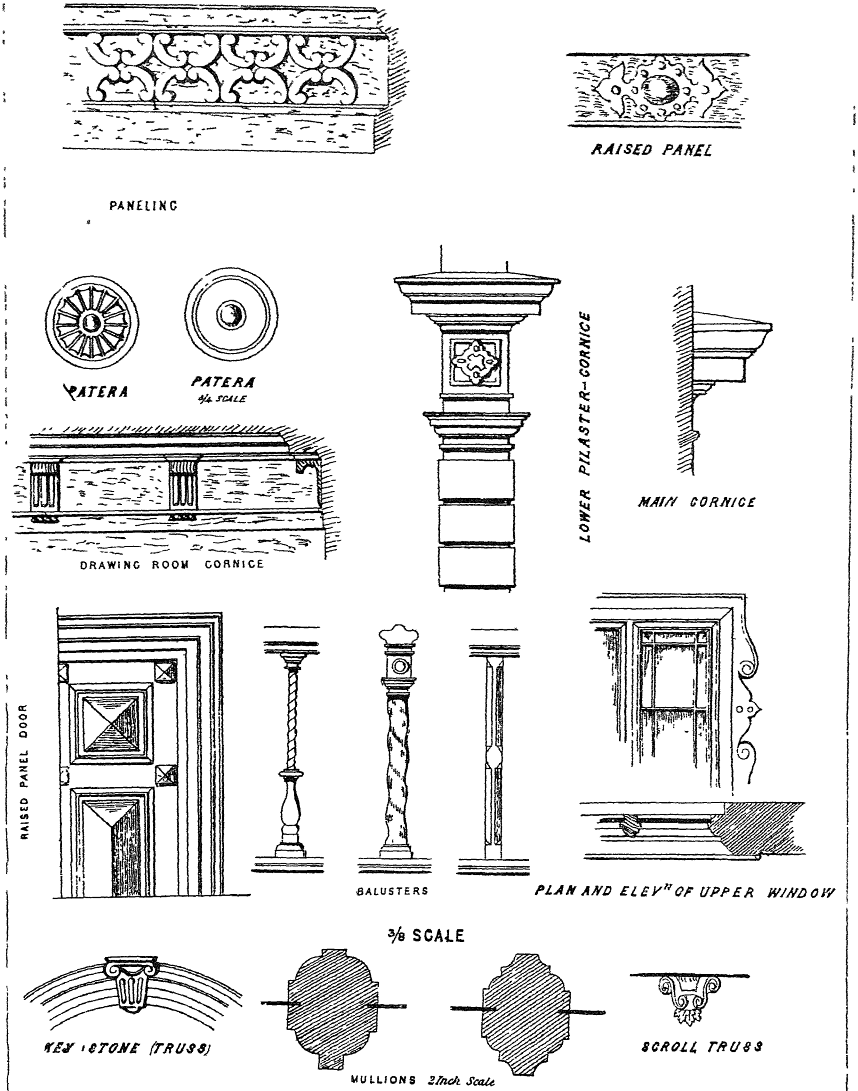
DESIGN FOR A BAY WINDOW—PART ELEVATION AND PLAN

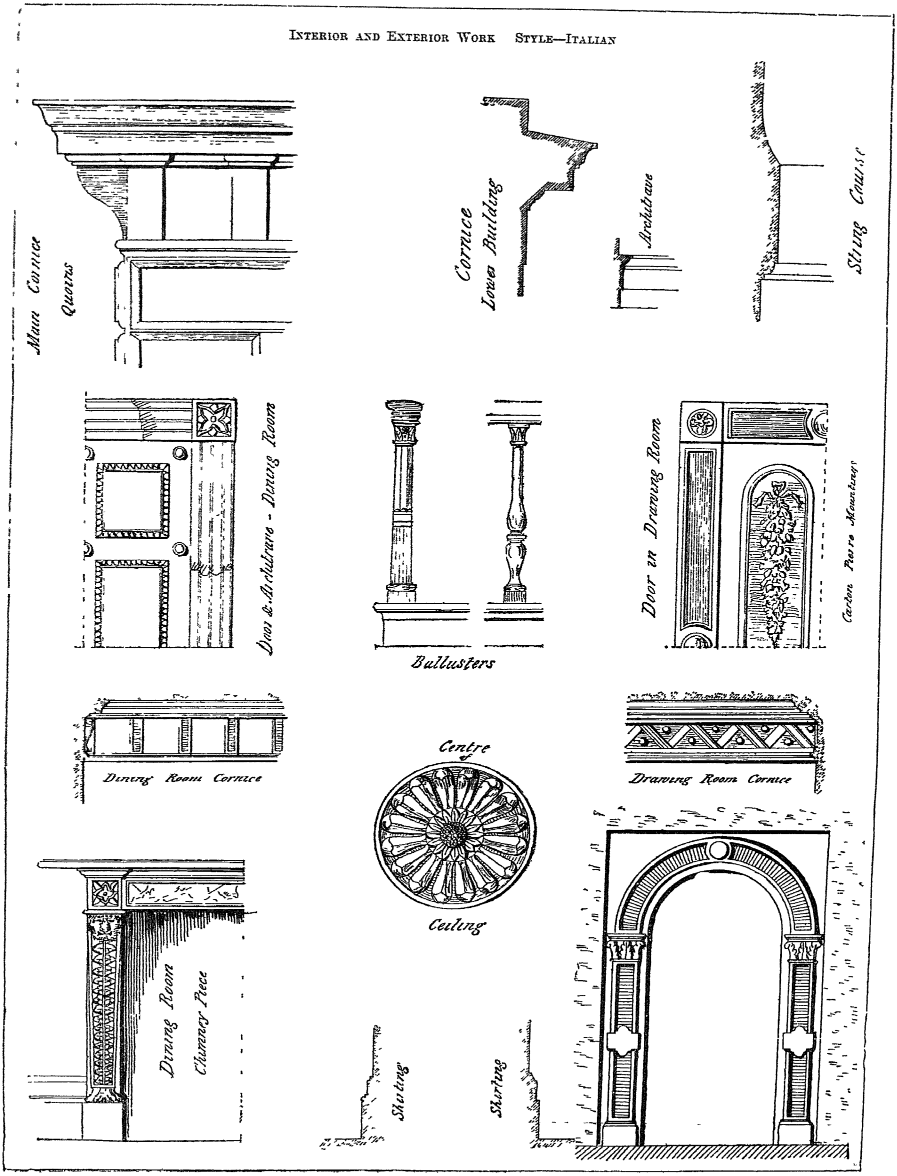


DETAILS OF BAY WINDOW IN PLATE XLI



DETAILS FOR INTERIOR AND EXTERIOR—STYLE ELIZABETHAN




INTERIOR AND EXTERIOR WORK STYLE—ITALIAN
Main Cornice
Quoins
Cornice
Lower Building
Architrave
String Course
Door & Architrave - Dining Room
Bullusters
Door in Drawing Room
Carton Pierre Mountings
Dining Room Cornice
Centre of Ceiling
Drawing Room Cornice
Dining Room Chimney Piece
Skirting
Skirting

[Plate XLIV.

INTERIOR DECORATION FOR DOMESTIC ARCHITECTURE—STYLE, ITALIAN

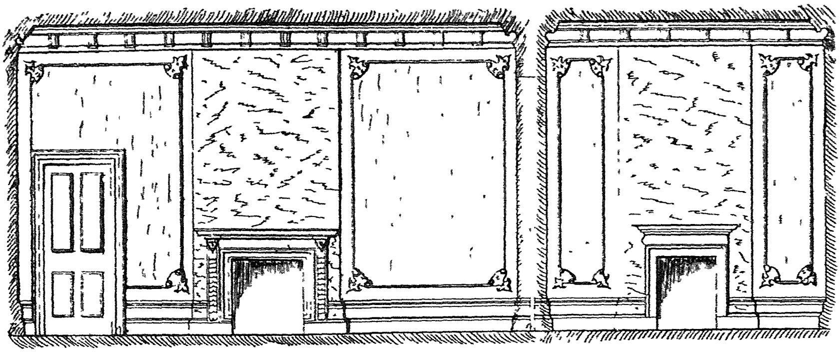


FIG 1

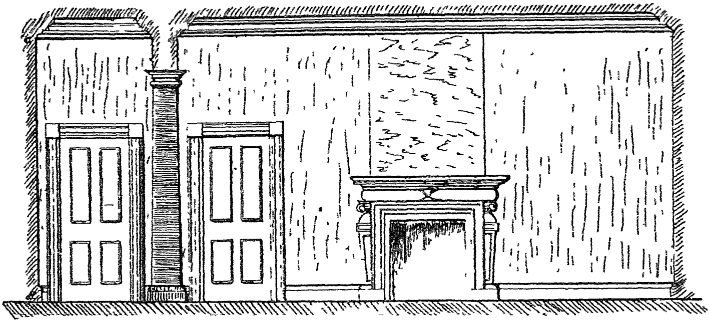


FIG 2

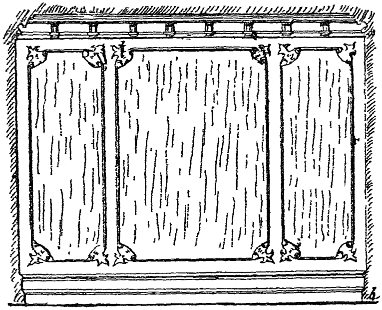


FIG 3

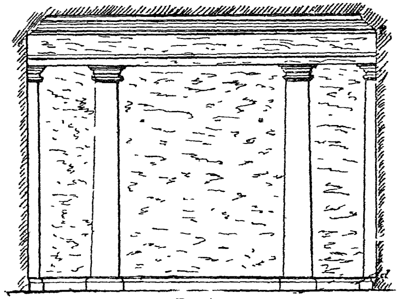


FIG 4

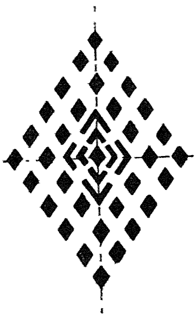


FIG 1

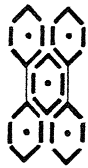


FIG 2

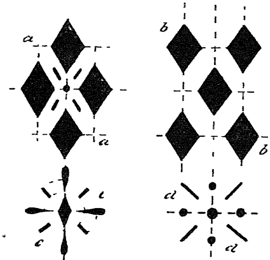


FIG. 3

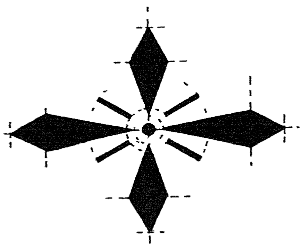


FIG 4.

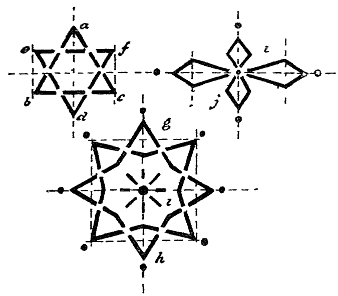


FIG 5

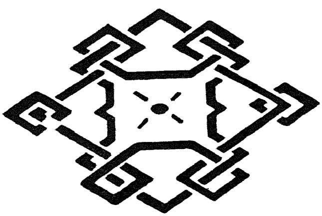


FIG 6

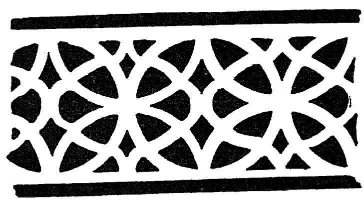


FIG 7

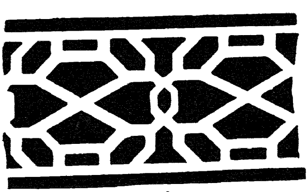


FIG 8

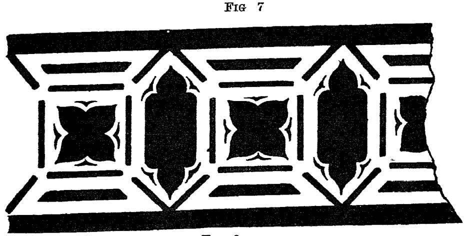


FIG 9

ELEMENTS OF DECORATIVE CARPENTRY AND JOINERY.

CHIEFLY FOR THE EXTERIOR WORK OF BUILDINGS, TIMBER STRUCTURES

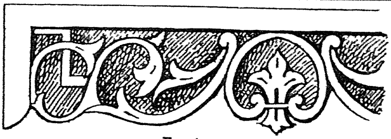


Fig 1.

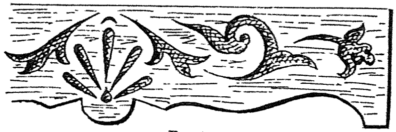


Fig 2.

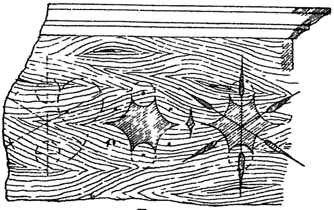


Fig. 3.

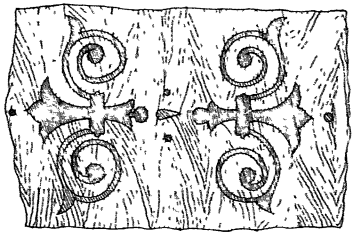


Fig 4

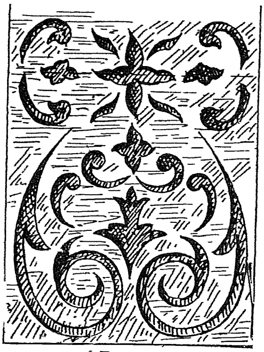
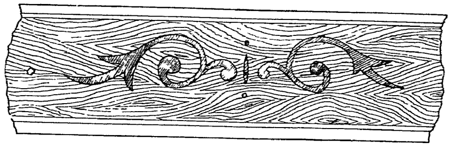


Fig 5



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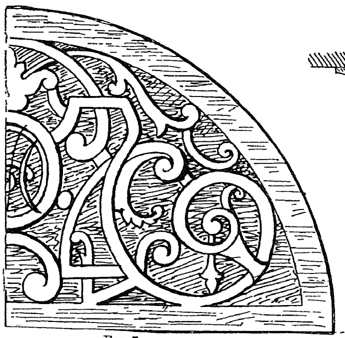


Fig 7

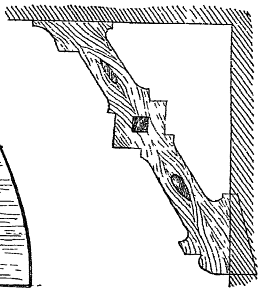


Fig 8

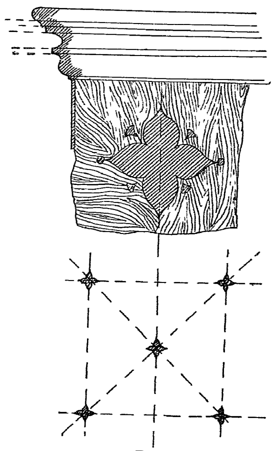


Fig 9

[*Plate XLVII*

FIG 1

FIG 2

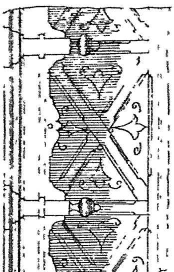


FIG 3

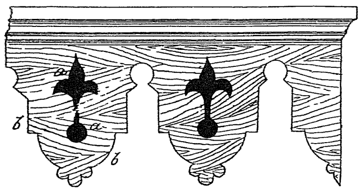


FIG 4

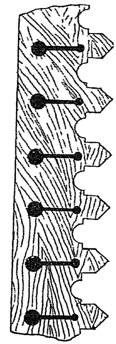


FIG 6

FIG 5

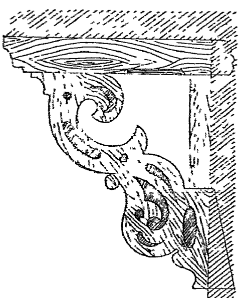


FIG 7

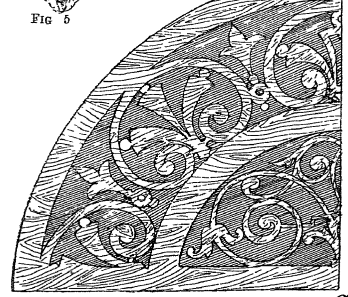


FIG 8

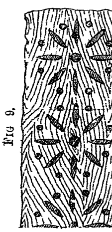


FIG 9.

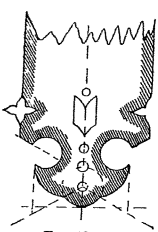


FIG 10

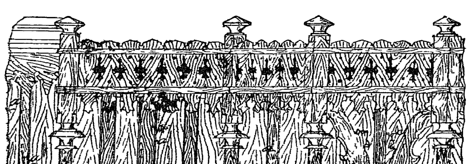


FIG 11

Designs for Gates, etc Figs 1, 2, Style—Domestic Gothic, Figs. 3, 4, Italian

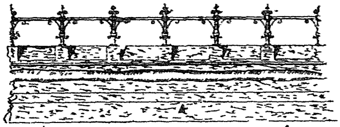


Fig 1 BALUSTRADE

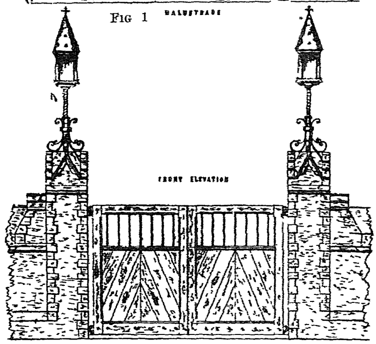


Fig 2

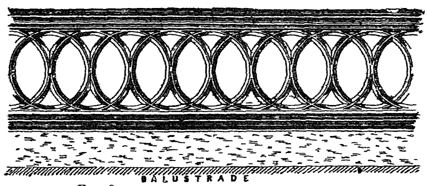


Fig 3 BALUSTRADE

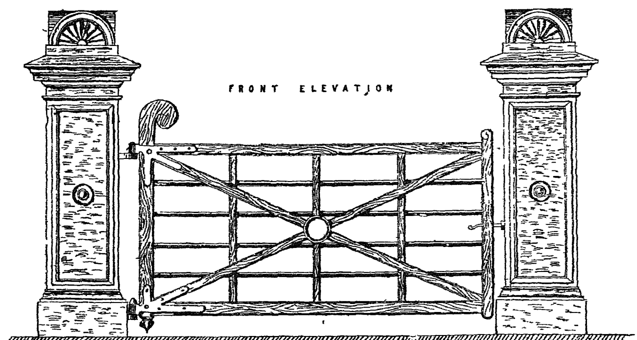
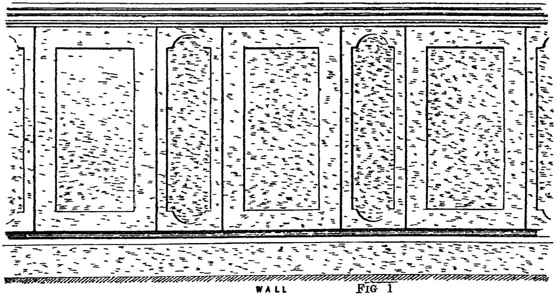


Fig 4

Designs for Gates, etc Style—Italian



WALL FIG 1

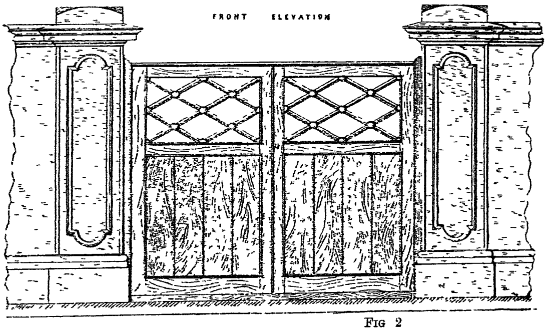


FIG 2

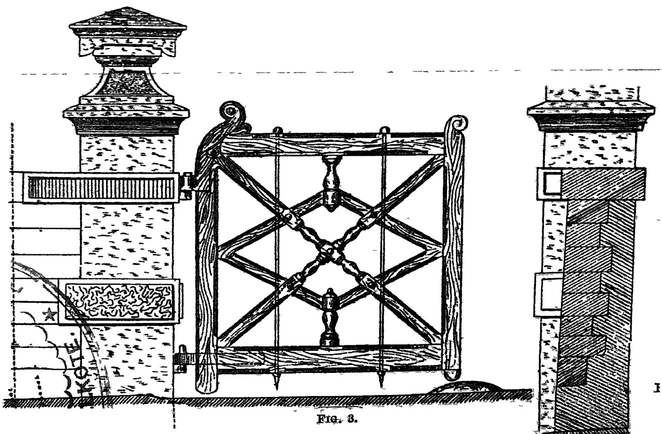


FIG. 3.